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Comparisons of Phytoseiid Predator Populations in Sprayed and Unsprayed Apple Orchards in Cache Valley, Utah

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COMPARISONS OF PHYTOSEIID PREDATOR POPULATIONS IN SPRAYED AND UNSPRAYED APPLE ORCHARDS IN CACHE VALLEY, UTAH

by

Yeboa A. Dodoo

A thesis submitted in partial fulfillment
of the requirements for the degree

of

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in

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To my wife, Florence, I am grateful for her encouragement and good company.

Yeboa A. Dodoo

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ABSTRACT

Comparisons of Phytoseiid Predator Populations in Sprayed and Unsprayed Apple Orchards in Cache Valley, Utah

by

Yeboa A. Dodoo, Master of Science

Utah State University, 1968

Major Professor: Dr. Donald W. Davis
Department: Zoology

A comparative study of phytoseiid populations was made of two well-cultivated and regularly sprayed apple orchards with two unsprayed orchards in Cache Valley, northern Utah.

Two phytoseiid species, *Typhlodromus mcgregori* Chant and *T. occidentalis* Nesbitt were observed on the apple leaves, under the bark, and occasionally in the litter and soil. *Amblyseius cucumeris* (Oudemans) occurred in the soil and litter and occasionally under bark. *T. mcgregori* was dominant in the unsprayed orchards, and *T. occidentalis* in the sprayed.

Of the phytophagous mites, which served as food for the phytoseiids, the two-spotted mite, *Tetranychus urticae* Koch was dominant. Other phytophagous mites were the brown mite, *Bryobia rubrioculus* (Scheuten), the European red mite, *Panonychus ulmi* (Koch), and the McDaniel mite, *Tetranychus mcdanieli* McGregor.

The study suggests *T. mcgregori* to be a non-specific, facultative predator of phytophagous mites. *T. mcgregori* was adversely affected by standard pesticide practices, but *T. occidentalis* survived in larger numbers.

The phytoseiids seem well adjusted to the environment of the unsprayed orchards and to contribute to the low phytophagous mite populations in those orchards. In the sprayed orchards, the phytoseiids failed to control the high populations of phytophagous mites which developed.

No statistical differences were found in the efficiencies of the mite brushing machine and Berlese funnels in removing either phytoseiid or phytophagous mites from apple leaves.

(46 pages)

INTRODUCTION

Phytoseiid mites are of economic importance because they feed on phytophagous mite pests of agricultural crops. Interest in the phytoseiid mites as predators of other mites was first shown by Parrott, Hodgkiss, and Schoene (1906) who reported that *Typhlodromus pomi* (Parrott), then known as *Seius pomi* Parrott, was valuable in controlling the apple and pear blister mite, *Eriophyes pyri* (Pgst).

Phytophagous mites today are important pests of apples as well as many other crops in many parts of the world. The extensive use of certain pesticides and cultural practices, such as manuring and pruning, has favored the increase of these mites. Pesticides destroy natural enemies of the phytophagous mites, and the cultural practices improve the quality of the trees, thus increasing their nutritive value to these pests. As a consequence orchards have become highly desirable environments in which insects and mites are often the most important fauna (Chant, 1959a). The spider mites of the family Tetranychidae are considered to be the most important of the plant-feeding mites.

Although chemical control of phytophagous mites is practiced, other methods may be more desirable, as chemical control is expensive, temporary, and not always effective. Biological control has been suggested in view of the successes that have been achieved by this method with other pests.

A variety of mites and insects, predaceous on mite pests, occurs widely in orchards (Gilliat, 1935; Pickett et al. 1946; Lord, 1949;

Collyer, 1952, 1953a, 1953b, 1953c; Muma, 1955; Collyer and Kirby, 1959). The insect predators include those of the orders Hemiptera, Thysanoptera, Neuroptera, Coleoptera, and Diptera. Muma (1955) also mentions parasitic fungi as being important in the natural control of orchard mites. However, interest in biological agents for the control of phytophagous mites has centered particularly on the predaceous mites of the family Phytoseiidae Berlese, 1916. In this study, predatory mites other than the phytoseiids were observed but not considered.

The present study was made to obtain a knowledge of the phytoseiid mite fauna in apple orchards in Cache Valley of northern Utah. It was part of a series of ecological studies of predaceous and phytophagous mites in Utah orchards, and was directly related to work on integrated control of spider mites. It was a comparative study made of two orchards which were sprayed regularly, with two which were unsprayed. The species of phytoseiid mites, their relative abundance and seasonal occurrence were determined in each orchard.

REVIEW OF LITERATURE

In 1935, Gilliat determined which mite and insect predators were the most important natural enemies of the European red mite, *Panonychus ulmi* (Koch) in Nova Scotia. As it was active for the entire growing season, the phytoseiid mite *Typhlodromus pomi* was considered to be probably the most important of all the predators attacking *P. ulmi* in Nova Scotia. Notes are given on the life history and habits of two mite and eight insect predators of *P. ulmi*. Gilliat also reported that Bordeaux mixture seriously reduced the numbers of *T. pomi*.

Cutright (1944) observed that sulfur sprays depressed populations of phytoseiid predators of *P. ulmi* in northeastern Ohio. This suppression of the predators resulted in injury by *P. ulmi*.

Pickett et al. (1946) also found *P. ulmi* to be numerous on sulfur-treated orchards in Nova Scotia as a result of the suppression of the natural enemies of this pest. In general, fewer species of arthropods, but not necessarily fewer individuals, were found on sulfur-treated areas. On copper-treated trees, a much larger number of species occurred but with fewer total individuals than on sulfur-treated trees. Also *P. ulmi* practically disappeared from copper-sprayed areas due to the establishment of populations of several predators which included a phytoseiid, several mirids, and a species of thrips.

In a study of mite species on apples in Connecticut, Garman (1948) noted that of the 25 or more species he found, nine or ten were plant feeders, about eleven were predators and five were of doubtful status. The phytoseiids were placed in the subfamily Phytoseiinae of the family Laelaptidae and a number of their distinguishing characteristics were given.

Collyer (1953a) described the life history and habits of forty-five species of predatory insects and mites which fed on the fruit tree red spider mite, P. ulmi in southeastern England. The following predatory mite species then included in the family Laelaptidae were described: Typhlodromus tiliae Oudms., Amblyseius hibisci (Chant) and Phytoseius spoofi (Oudms.)

Also in 1953, she (Collyer, 1953c) studied the relative importance of the different predatory species in relation to P. ulmi in neglected and commercial apple orchards in England. She found the predator-mite relationship in well-kept commercial orchards to vary greatly and to be mainly dependent on the spray program. The predaceous mites were the only predators which had a life cycle closely resembling that of P. ulmi. It was concluded that if any balanced state between P. ulmi and its predators was to be achieved in orchards, these predaceous mites would play an important part, together with a succession of insect predators.

Huffaker and Kennett (1953) made extensive population studies of the cyclamen mite, Stenotarsonemus pallidus (Banks) and the phytoseiid predators Typhlodromus reticulatus Oudms. and Amblyseius cucumeris (Oudms.) on strawberries in California. The predators effectively controlled the cyclamen mite in third- and fourth-year fields when their activities were not inhibited by parathion, used in the control of other pests. Control in second-year fields was erratic due partly, it was felt, to the lag in appearance of predators. A long-term greenhouse study also verified the fact that the predators could maintain the host at a considerably low level. Both hand removal and chemical removal of predators increased the numbers of the cyclamen mite.

The biology of the phytoseiid mite, *Amblyseius fallacis* (Garman) was studied by Ballard (1954), using a modified Huffaker cell with *Tetranychus urticae* Koch as host. Length of development and longevity, number of eggs laid per female, feeding capacity, and behavior of *A. fallacis* were studied extensively. No phytophagy was noted on the part of the predator and cannibalism occurred only under prolonged starvation.

Fleschner and Ricker (1954) observed the feeding habits of phytoseiid mites on citrus and avocado trees in southern California. *Amblyseius hibisci* fed on the red spider mite *P. ulmi*, the citrus bud mite, *Aceria sheldoni* (Ewing), and the avocado brown mite, *Oligonychus coiti* McG. *Typhlodromus conspiicus* (Garman) was unique in being the only phytoseiid tested that would feed or reproduce on the pallid mite, *Tydeus californicus* (Banks). *Typhlodromus longipilus* Nesbitt fed on *O. coiti* and *T. urticae* and *A.* sp. (near *hibisci*) fed on a wide range of tetranychid mites.

Hantsbarger and O'Neill (1954) found *T. longipilus* to be the only predaceous mite in apple orchards in North-Central Washington that was feeding on tetranychid mites. *T. longipilus* was also found on a number of wild plants, as was *Typhlodromus rhenanus* (Oudms). *T. longipilus* fed voraciously, more readily attacking the eggs and nymphs of the spider mites.

In 1955, Chant observed that the dorsal setae of the overwintering generation of females of many phytoseiid mites were much more strongly serrated than those of summer generations. Also, the degree of sclerotization of the former was frequently greater. This was particularly true of Typhlodromus vitis Oudms., which overwintered under the bark of hazel, Corylus avellana L.

Collyer and Kirby (1955) studied a number of factors affecting the balance of phytophagous and predaceous mites on apples in southeastern England. They found that higher populations of Panonychus ulmi developed following lime-sulfur sprays than after glyodin or captan. Conversely, higher populations of phytoseiid mites were present on glyodin- or captan-treated trees than those receiving lime-sulfur.

Collyer (1956) gave notes on the biology of a number of phytoseiid mites, mostly associated with fruit trees in southeastern England. Certain measurements and other characters that are of value in separating species are given. Typhlodromus tiliae, Amblyseius hibisci and Phytoseius macropilis (Banks) were abundant on commercially-grown apple.

Herbert in 1956 studied some factors in the life-history of the predaceous mite, T. tiliae. Data are given on the duration of the immature stages, the lengths of the pre-oviposition and oviposition periods, the number of eggs laid per female, and longevity. When T. tiliae was maintained at 70F and consumed 20 eggs of Tetranychus urticae per day, a generation was completed in 13 days. However, at 60F with other conditions constant, a generation was completed in 19 days.

In studies on the occurrence of phytoseiid mites in southern British Columbia, Anderson, Morgan, and Chant (1958) found twenty-eight species, of which fourteen were collected in orchards. Only three of these mites, however, occurred in relatively large numbers. These were Typhlodromus occidentalis Nesbitt, T. rhenanus, and Phytoseius macropilis. It was reported that cover crops did not serve as a reservoir for the species found on the trees.

Herbert (1958) described a new species of predaceous mite, Typhlodromus corticis, with notes on its life history and food habits as well as those of T. tiliae. T. corticis was found on the bark of apple trees in Nova Scotia. It was never found on the foliage. T. corticis was similar in structure to T. tiliae but differed from it in habits. T. corticis developed and laid eggs when fed larvae of Bryobia rubrioculus (Scheuten) or eggs of Panonychus ulmi. When protonymphs of T. corticis were fed eggs of Tetranychus urticae, they did not develop to deutonymphs. T. tiliae developed and laid eggs when fed the larvae of B. rubrioculus, P. ulmi, or T. urticae.

Kennett (1958) described some phytoseiid mites in the subfamilies Phytoseiinae and Aceosejinae. A key was given to the species of these subfamilies found on strawberries in central California. Two new species were described in Amblyseius, two in Typhlodromus, and one in Lasioseius, and Phytoseiulus speyeri Evans was placed in synonymy with Phytoseius macropilis. Some earlier specific misidentifications were corrected, and several erroneous interpretations of the chaetotaxy of Amblyseius were rectified.

Also in 1958, Collyer studied the effect of various predaceous mites on the development of Panonychus ulmi populations. When 5, 25, or 50 females of P. ulmi were placed on a plant together with five females of Typhlodromus tiliae, the P. ulmi population in each case remained over a three-month period at a density of less than one mite per leaf. In the absence of T. tiliae, the same numbers of P. ulmi as before developed to over 3,000 per leaf in eleven weeks. It was also shown that both the size of the host plant and the initial ratio of P. ulmi and T. tiliae affected the development of the T. tiliae populations. Both *T. tiliae* and *Amblyseius hibisci* effectively controlled *P. ulmi* but other phytoseiid species were ineffective.

In 1959, Collyer and Kirby observed that *T. tiliae* was more plentiful on apple trees treated with captan in southeastern England. On trees treated with lime sulfur and captan, the numbers of *T. tiliae* were lower than on trees treated only with lime-sulfur. The densities of *T. tiliae* showed an inverse correlation with those of *Panonychus ulmi*. This inverse correlation between *P. ulmi* and *T. tiliae* lent support to the idea that phytoseiid mites were an important factor in the biological control of *P. ulmi* in southeastern England.

Chant (1959a) studied the bionomics of seven species of phytoseiid mites in southeastern England. None of the species exhibited plant-specificity, though a preference for certain habitats was at times shown. Each species overwintered as adult females, some on evergreen plants and others in bark crevices. Winter mortality was severe. Various aspects of the ecology of *Typhlodromus pyri* Scheuten were studied and related to those of its prey, *P. ulmi*. The predator was inefficient and partially ineffective. Though *T. pyri* preyed on *P. ulmi* and other small *acarines*, plant food such as fungi and pollen was acceptable and allowed both development and reproduction.

Herbert (1959) studied the feeding ranges of six species of predaceous mites. *Typhlodromus tiliae* fed on the eggs, larvae, nymphs and adults of *Panonychus ulmi* and *Bryobia arborea* M. and A., and on the eggs, nymphs and adults of *Tetranychus urticae*. *Amblyseius hibisci* fed on all stages of the phytophagous mites except the overwintered eggs of *P. ulmi* and *B. arborea*. Also *Typhlodromus rhenanus* and

Phytoseius macropilis did not feed on these overwintered eggs nor on the adults of *T. urticae*. *Typhlodromus corticis* fed on all stages of *P. ulmi* and *B. arborea*, and on the eggs of *T. urticae*. *Typhlodromus fallacis* fed only on the eggs, nymphs and adults of *T. urticae*.

In studies on *Typhlodromus occidentalis*, Chant (1961a) found that the oviposition and prey consumption rates of this predaceous mite depended on the number of prey available. *T. occidentalis* required very little animal food for oviposition. In the same year, he (Chant, 1961b) conducted a biological control experiment of *Tetranychus urticae*, using the predaceous mite, *Phytoseiulus persimilis* Athias-Henriot. *P. persimilis* controlled *T. urticae* very well and eventually almost eliminated it. The predator was voracious, rapidly reproducing and developing, highly mobile, and largely dependent on its prey for food. Its distribution on the host plant was well integrated with that of its prey. The predator did not establish itself except where the prey was present.

In 1962, Putman studied the life history and behavior of *Typhlodromus caudiglans* Schuster in Ontario. Nine generations of the mite were recorded and the duration of the immature stages was determined at various temperatures. The females required repeated insemination. Diapause was induced by a 12-hour photoperiod and inhibited by a period of 14 hours or longer, and by continuous light or darkness. *T. caudiglans* exhibited low photokinesis, low thigmokinesis, negative geotropism, and a tendency to remain on the lower side of horizontal surfaces. The young of *T. caudiglans* reached maturity, and the females oviposited, when fed a number of species of tetranychid mites as well as pollen. A few young reached maturity after an abnormally long time on a fungal diet.

McMurtry and Scriven (1964a) observed the biology of the phytoseiid mite, Typhlodromus rickeri (Chant) which was introduced into California from India. The mite fed and reproduced on the tetranychid mites, Panonychus citri (McGregor), Tetranychus mcdanieli McGregor, Tetranychus cinnabarinus (Boisduval), Eotetranychus lewisi (McGregor), and Oligonychus punicae (Hirst), and on the eriophyid mite, Phyllocoptruta oleivora (Ashmead). On the other hand, only limited feeding and reproduction occurred on pollen, scale crawlers, and honey dew. At 72F the average generation time from egg to egg was 9.4 days. The rate of prey consumption by T. rickeri was closely correlated with its rate of oviposition.

In the same year, McMurtry and Scriven (1964b) also found that the adults of Amblyseius hibisci fed and reproduced readily on Panonychus citri, Oligonychus punicae, and Eotetranychus sexmaculatus (Riley). Reproduction was, however, low and mortality high on Tetranychus cinnabarinus. The predators were hindered by, and often trapped in, the webbing of T. cinnabarinus. Reproduction and development of A. hibisci also readily occurred on pollen from various plant species. Developmental period was shorter and reproductive rate higher on pollen than on tetranychid mite prey. However, when mite prey and pollen were both available, A. hibisci fed on both without showing any distinct preference.

Burrel and McCormick in 1964 conducted laboratory studies to determine the host preferences of the predaceous mites Typhlodromus longipilus, T. occidentalis, T. rhenanus, Amblyseius cucumeris, and A. fallacis. Various species of tetranychid mites, especially T.

mcdanieli, were the most suitable hosts for *T. longipilus* and for both *A. cucumeris* and *A. fallacis*. *A. cucumeris* was the only one of these predators that could develop satisfactorily on *Panonychus ulmi* and on *Bryobia rubrioculus*. *A. cucumeris* was not tested with the apple rust mite, *Vasates schechtendali* (Nal.), but this mite proved an excellent and readily acceptable host for the other four predators.

McMurtry and Johnson (1965) observed some factors influencing the abundance of *Amblyseius hibisci* in southern California. The phytoseiid mite often attained its highest population density in the spring or early summer, when mite prey populations were very low. Rapid increases of *A. hibisci* followed the beginning of blossoming and egg production peaks showed a close correlation with peaks in flowering intensity. In one orchard, the population of *A. hibisci* reached unusually high levels, apparently as a result of large quantities of pollen drifting from adjacent plants of *Ricinus communis* L.

Lee and Davis (1968) studied the bionomics of *Typhlodromus occidentalis*, using *Tetranychus urticae* as prey. The behavior of each developmental stage was described, with observations on duration and feeding capability. The average developmental time from egg to adult was 6.3 days at 75F. The study indicated that *T. occidentalis* was of value in controlling orchard-inhabiting tetranychid mites in Utah.

METHODS AND MATERIALS

Three types of samples were collected in 1966 and 1967 from each of two unsprayed and two commercially sprayed apple orchards in Cache Valley, northern Utah. Apple leaves, apple bark, and orchard litter and soil were collected from each orchard and brought to the laboratory to determine the presence of both phytoseiid and phytophagous mites. Many of the mites from each sample were mounted on slides in Hoyer's solution and later identified under the phase microscope.

The first sprayed orchard (to be known in this study as "Treated Orchard No. 1") was sprayed, at one time or another during the period of the study, with oil plus diazinon, Guthion, Bordeaux mixture, Karathane and Imidan. The second sprayed orchard (Treated Orchard No. 2) was during the same period sprayed with Guthion, Tedion, Kelthane, parathion, lime sulfur and Morocide.

Leaf Samples

Leaves brushed with the mite brushing machine. From July 5, 1966, through November 1, 1966, and also from June 6, 1967, through July 31, 1967, 100 mature apple leaves were collected every week from each of the four apple orchards and brought to the laboratory. A brushing machine (Henderson and McBurnie, 1943; Morgan et al., 1955) was used to remove the mites from the leaves.

The machine (Fig. 1) consists of a small electric motor driving two contrarotating spiral brushes, and a turntable mounted about six inches below the brushes. A glass plate coated with a thin layer of paraffin oil is placed on the turntable to trap the mites.

Each leaf was inserted between the whirling brushes and then withdrawn; first one end of the leaf was brushed and then the other. The glass plate was then placed on a disc divided into 12 equal sections. The mites on three of these sections were counted under a dissecting microscope. Separate counts of phytoseiid and phytophagous mites were made. Each number was multiplied four times to obtain the number of mites per 100 leaves.

Leaves put into Berlese funnels. From June 6, 1967, through July 31, 1967, 100 mature apple leaves were collected weekly from each of the same four orchards. The leaves were brought into the laboratory and put into Berlese funnels (Fig. 2) to collect the mites. The funnels were allowed to run for 48 hours and the mites were collected in alcohol. The numbers of phytoseiid and phytophagous mites were again counted separately.

This method of collecting mites from apple leaves was adopted primarily to compare the efficiency of the Berlese funnels in removing mites from the leaves with that of the mite brushing machine.

Bark Samples

Weekly collections of bark from apple trees in the orchards were made from July 5, 1966, through September 20, 1966, and also from April 4, 1967, through May 23, 1967. Five hundred grams of bark were collected every week from each of the orchards. The bark samples were put into Berlese funnels (Fig 2) in the laboratory and the mites were collected. Separate counts of phytoseiid and phytophagous mites were made.

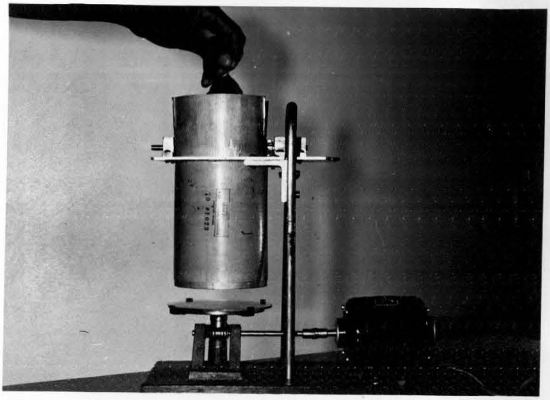


Figure 1. The mite brushing machine used for removing mites from leaves

Figure 2. Collecting mites with Berlese funnels

Litter and Soil Samples

Five hundred gram samples of litter composed primarily of decaying apple leaves with soil were occasionally collected from each orchard and put into Berlese funnels as before to collect the mites. Phytoseiid and phytophagous mites were again counted separately. Three such collections were made in 1966 and five in 1967.

Analysis of Data

The data were analyzed statistically, using the analysis of variance and the F test of significance.

RESULTS

Phytoseiid Species

For the purpose of this study, two major genera of Phytoseiidae were considered: Typhlodromus Scheuten and Amblyseius Berlese. Some authors, however, divide these two genera into additional genera.

Two species of Typhlodromus were found in the orchards. They were Typhlodromus mcgregori Chant (Fig. 3) and T. occidentalis Nesbitt (Fig. 4). These phytoseiids were observed on the foliage, under the bark, and occasionally in the litter and soil samples. Amblyseius cucumeris Oudemans was observed in the soil and litter samples and only occasionally under bark.

The two species of Typhlodromus were identified under the phase microscope primarily by the length of the peritremes and prolateral setae. The peritremes of T. occidentalis are much shorter than those of T. mcgregori (Schuster and Pritchard, 1963). The prolateral setae in T. occidentalis are distinctly longer than the distances between their bases while those of T. mcgregori are almost equal to, or only slightly longer than, the distances between their bases (Chant, 1959b; Schuster and Pritchard, 1963).

A. cucumeris was identified by the length of the first four prolateral setae and the shape of the ventrianal plate. The first four prolateral setae are approximately half as long as the distances between their bases. The ventrianal plate is triangular (Chant, 1959b).

Of the two Typhlodromus species, T. mcgregori was more abundant on unsprayed trees than T. occidentalis. The latter was more abundant

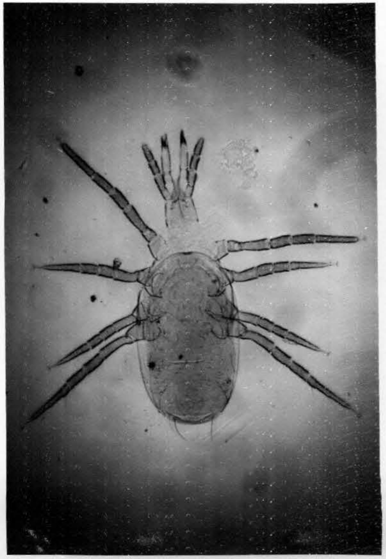


Figure 3. *Typhlodromus mcgregori* Chant

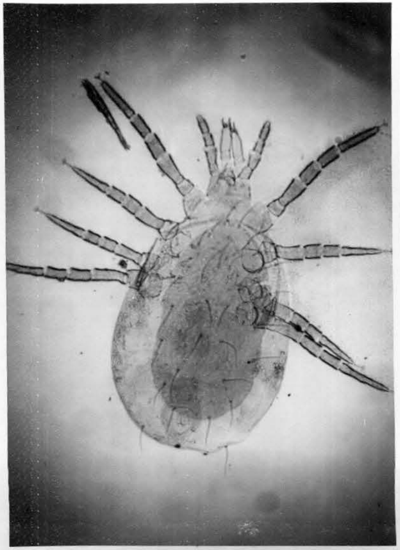


Figure 4. *Typhlodromus occidentalis* Nesbitt

on sprayed trees. The exact proportions were not determined in all of the samples.

Phytoseiid Populations from Sprayed and Unsprayed Orchards

Tables 1 and 2 show the mean numbers of combined *T. mcgregori* and *T. occidentalis* from the unsprayed and sprayed orchards. Table 3 includes a large proportion of *Amblyseius* as well as the two species of *Typhlodromus*. *Amblyseius cucumeris* was the major species in the soil and litter samples.

The total numbers of *Typhlodromus* (*T. mcgregori* and *T. occidentalis*) were greater at the 5 per cent level of significance on the apple leaves of the untreated orchards than on the leaves of the treated orchards. The difference, however, was not significant at the 1 per cent level. The difference in the total numbers of *Typhlodromus* from untreated bark and from treated bark was not significant at the 5 per cent level.

In most of the foliage samples, the *Typhlodromus* numbers were higher in the untreated orchards during the early part of the summer. The population of *Typhlodromus* started later on the treated leaves than on the untreated leaves. The *Typhlodromus* numbers from the untreated bark showed very little fluctuation but higher numbers of the phytoseiids were attained during August and September in the treated bark. During the early spring, prior to any sprays, there were almost no differences in *Typhlodromus* numbers from bark samples. *Amblyseius* numbers were less in the soil and litter samples from sprayed orchards.

Table 1. Mean[a] numbers of _Typhlodromus_ mites recorded from 100 apple leaves, using the mite brushing machine[b]

Date of collection	Mean number of _Typhlodromus_ mites	
	Untreated orchards	Treated orchards
_1966_		
Jul. 5	4	0
Jul. 12	18	0
Jul. 19	54	0
Jul. 26	58	0
Aug. 2	118	6
Aug. 9	84	6
Aug. 16	114	10
Aug. 23	66	14
Aug. 30	50	48
Sep. 7	78	8
Sep. 13	112	22
Sep. 20	100	24
Sep. 27	60	16
Oct. 4	54	10
Oct. 11	38	4
Oct. 18	14	2
Oct. 25	6	2
Nov. 1	0	0
_1967_		
Jun. 6	4	0
Jun. 13	0	0
Jun. 20	6	2
Jun. 27	12	2
Jul. 4	26	0
Jul. 11	30	0
Jul. 18	30	0
Jul. 25	32	0
Jul. 31	32	0

[a] Mean of two values

[b] Differences significant at 5 per cent level but not at 1 per cent

Phytophagous Mites Found

The two-spotted mite, _Tetranychus urticae_ Koch was the major phytophagous mite observed. Other phytophagous mites observed were

Table 2. Mean[a] numbers of Typhlodromus mites recorded from 500 gm. of apple bark[b]

Date of Collection	Mean number of Typhlodromus mites	
	Untreated orchards	Treated orchards
1966		
Jul. 5	0	0
Jul. 12	0	0
Jul. 19	2.0	0
Jul. 26	3.5	0
Aug. 2	5.5	1.0
Aug. 9	2.0	0
Aug. 16	4.0	0
Aug. 23	1.5	1.5
Aug. 30	1.5	17.0
Sep. 7	0.5	1.5
Sep. 13	0.5	21.5
Sep. 20	1.0	24.5
1967		
Apr. 4	6.5	18.5
Apr. 11	5.5	1.5
Apr. 18	6.0	7.0
May 2	28.5	4.0
May 9	2.0	13.5
May 16	0	2.0
May 23	1.0	0

[a] Mean of two values

[b] Differences not significant at 5 per cent level

the brown mite, Bryobia rubrioculus (Scheuten), the European red mite, Panonychus ulmi (Koch), and the McDaniel mite, Tetranychus mcdanieli McGregor.

Other Mites Found

Mites of the family Tydeidae were occasionally recorded from the leaves and frequently from the bark while members of the group

Table 3. Mean[a] numbers of phytoseiid mites recorded from 500 gm. of litter and soil

Date of Collection	Mean numbers of mites	
	Untreated orchards	Treated orchards
<u>1966</u>		
Aug. 2	0.5	0
Aug. 23	2.0	3.5
Sep. 6	7.0	1.0
<u>1967</u>		
Apr. 11	10.0	0
Apr. 25	2.5	6.0
May 9	5.0	0
May 23	0.5	0
Jun. 13	4.0	0

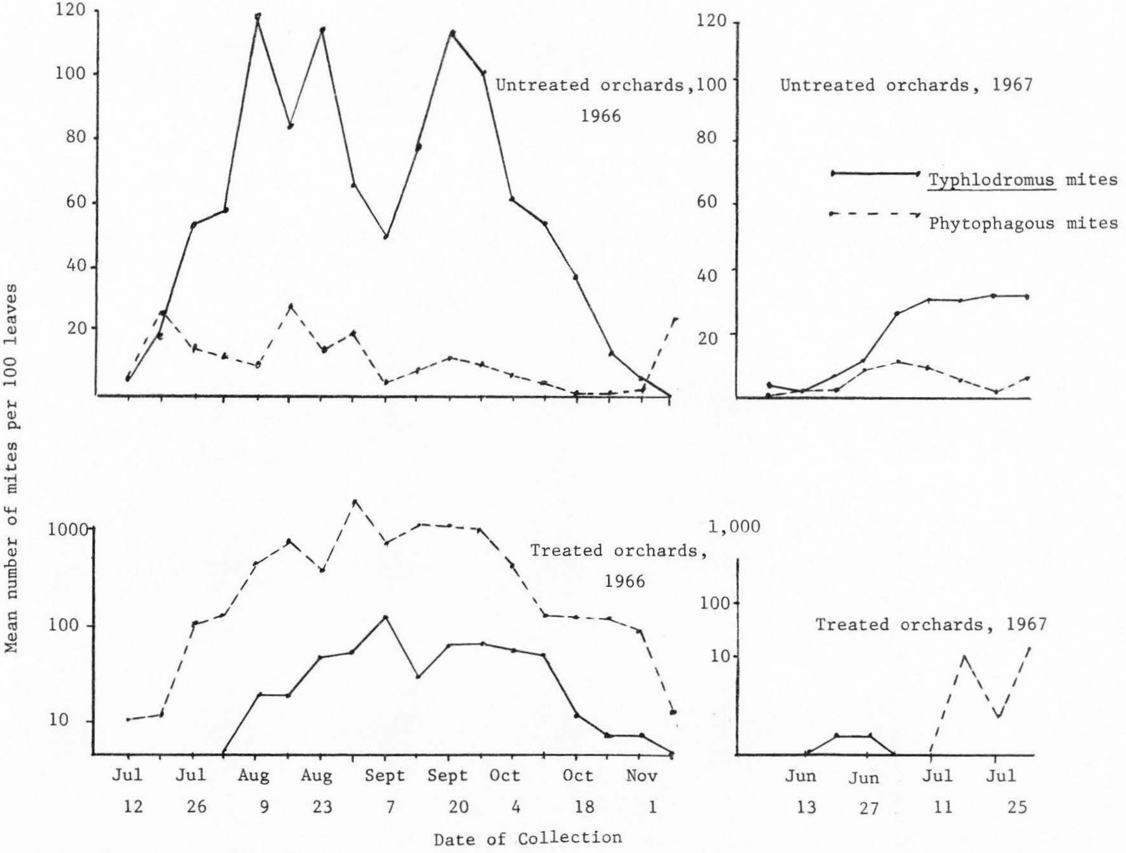
[a] Mean of two values

Oribatei were often obtained from the soil and litter samples. The population trends of these mites were, however, not followed.

Predator-prey Relationship

The occurrence and relationship of the predators and prey mites are shown in Figures 5 and 6. The population densities of the prey mites on the untreated leaves were usually lower than those of Typhlodromus but they were higher on the treated leaves than those of the phytoseiids.

The occurrence of the tetranychid mites on the untreated leaves started early and showed little fluctuation. T. mcgregori also occurred earlier on the untreated leaves than T. occidentalis. The phytoseiids were most abundant during August and September.


Mean number of mites per 100 leaves
120
100
80
60
40
20
Untreated orchards, 1966
120
100
80
60
40
20
Untreated orchards, 1967
Typhlodromus mites
Phytophagous mites
1000
100
10
Treated orchards, 1966
1,000
100
10
Treated orchards, 1967
Jul 12
Jul 26
Aug 9
Aug 23
Sept 7
Sept 20
Oct 4
Oct 18
Nov 1
Jun 13
Jun 27
Jul 11
Jul 25
Date of Collection

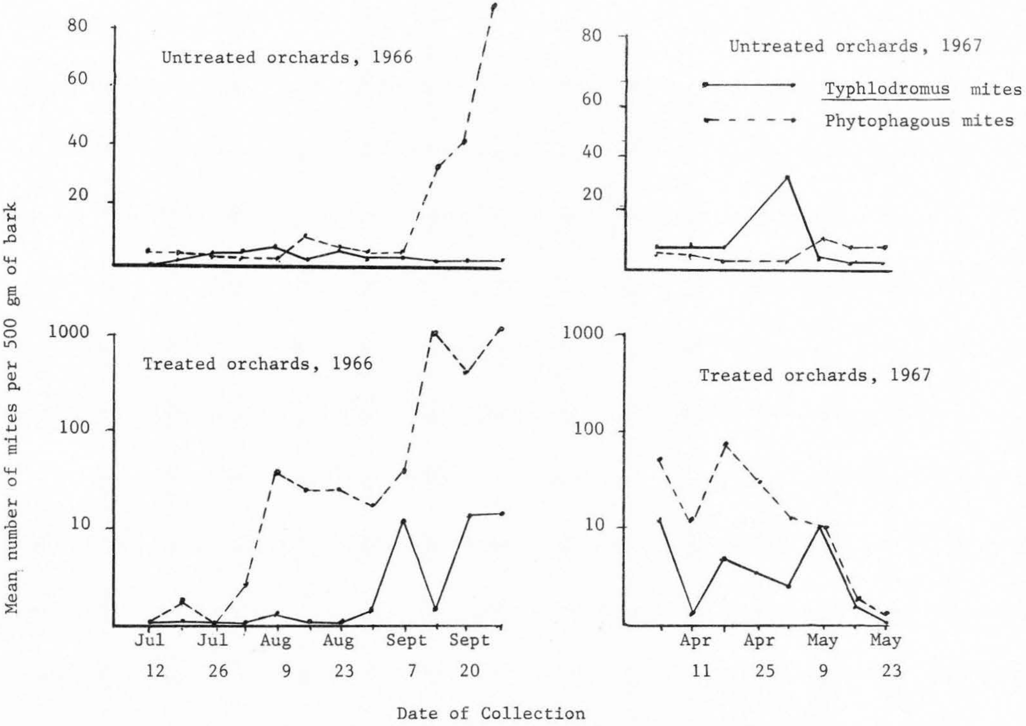


Figure 6. Seasonal occurrence of _Typhlodromus_ and phytophagous mites in apple bark

On the treated leaves, the phytoseiid populations started later than those of the phytophagous mites but both phytophagous and predatory mites were abundant in August and September.

Comparison of the Efficiencies of the Mite Brushing Machine and Berlese Funnels in Removing Mites from Apple Leaves

Weekly collections of 100 apple leaves from each of the orchards -- made from June 6, 1967, through July 31, 1967 -- were put into Berlese funnels to collect the mites. The numbers of mites so collected were compared with those collected during the same period with the mite brushing machine. Tables 4 and 5 show the numbers of *Typhlodromus* and phytophagous mites collected by the two methods. There were no significant differences at the 5 per cent level between the numbers of both phytoseiid and phytophagous mites collected by the two methods, although the brushing machine appeared to be somewhat superior for the phytoseiids.

Table 4. Numbers of Typhlodromus mites collected with the mite brushing machine and Berlese funnels[a]

Date of Collection	Number of Typhlodromus mites	
	Mite brushing machine	Berlese funnel
1967		
June 6	8	11
June 13	0	13
June 20	16	29
June 27	28	43
July 4	52	28
July 11	60	53
July 18	60	35
July 25	64	25
July 31	64	26

[a] Differences not significant at 5 per cent level

Table 5. Numbers of phytophagous mites collected with the mite brushing machine and with Berlese funnels[a]

Date of Collection	Number of phytophagous mites	
	Mite brushing machine	Berlese funnel
1967		
June 6	0	5
June 13	4	8
June 20	4	2
June 27	20	5
July 4	24	24
July 11	20	18
July 18	36	10
July 25	12	4
July 31	44	32

[a] Differences not significant at 5 per cent level

DISCUSSION

The present study shows that Typhlodromus mcgregori is the predominant phytoseiid in unsprayed apple orchards in Cache Valley, northern Utah. T. occidentalis abounds in sprayed orchards. The latter finding agrees with that of Lee (1966) who found T. occidentalis to be the most important phytoseiid in sprayed apple orchards in North Salt Lake City, Utah.

T. mcgregori occurred earlier. All phytoseiids were most abundant during August and September. This observation is also in agreement with Lee's finding on T. occidentalis. The spider mites which served as food also occurred early, with their numbers becoming most abundant on the leaves during August and early September.

The results of the study indicate that T. mcgregori was more susceptible to the application of pesticides. The population density of Typhlodromus on the leaves of untreated trees, where T. mcgregori predominated, was greater at the 5 per cent level of significance, than on the treated leaves. The difference in total numbers of phytoseiid mites from the untreated and treated bark was not significant at 5 per cent.

The proportionally greater numbers of T. occidentalis on the sprayed trees indicates that this mite probably has some resistance to the pesticides or to the method of application used in the spray programs.

The suppression of T. mcgregori populations by pesticides parallels the findings of many workers with other phytoseiids. Gilliat in 1935 observed that Bordeaux mixture seriously reduced the numbers of

Typhlodromus pomi while Garman (1938), Collyer (1953c), and Collyer and Kirby (1955), noted that lime sulfur adversely affected the phytoseiid predators of the European red mite, *Panonychus ulmi*. In their study, Morgan et al. (1958) found that *Typhlodromus* spp. which preyed on *P. ulmi*, were nearly eliminated by Karathane. It will be recalled that many of these pesticides were also applied in the treated orchards of the present study. It can be seen, therefore, that the nature of the spray program in treated orchards adversely affects the population density of some phytoseiids.

The population density of *Typhlodromus* on the untreated leaves was sometimes higher than that of the spider mites (Fig. 5). In these instances, *T. mcgregori* was the dominant phytoseiid. This indicates that *T. mcgregori* probably uses food items other than spider mite prey for its survival. The findings of many workers lend support to this view. Collyer (1956) showed in laboratory tests that certain phytoseiids could survive for a considerable length of time on plant food but no eggs were laid. Chant (1959a) mentions that he and C. V. G. Morgan in 1952 demonstrated the phytophagous habit of the phytoseiid, *Typhlodromus rhenanus* in Western Canada by staining plants with systemic dyes and later observing colored intestines in mites that were allowed only the treated leaves. This was repeated later in England with *Typhlodromus pyri* and *Amblyseius hibisci*. Chant also showed in his study that although *T. pyri* was predaceous on *P. ulmi* and other acarines, plant food materials such as fungi, pollen and leaf juices were acceptable and allowed both development and reproduction. Putman (1962) observed the young of *Typhlodromus caudiglans* to develop and oviposit on a diet of fresh pollen. McMurtry and Scriven (1964b) made a similar observation with A. hibisci feeding on pollen from various plant species.

Lee (1966), however, found that when larvae of T. occidentalis were confined on pollen, fungal spores, plant juices or water only, instead of mites, the predators could only develop to the protonymphal stage and their longevity was reduced to only three to four days. Perhaps the inability of T. occidentalis to thrive on food other than mites partly accounts for its low densities in comparison to T. mcgregori on trees with few spider mites. Chant (1961a) showed that the oviposition and prey consumption rates of T. occidentalis depended on the number of prey available; or in other words, this predator is dependent on prey density factors. Since the population of spider mites was lower on the untreated leaves, this finding of Chant's may also in part explain the low density of T. occidentalis on the untreated leaves.

A number of field observations have also demonstrated the ability of certain phytoseiids to survive in the absence of mite food and to utilize non-animal food. Collyer (1956) found that the distribution of phytoseiids in southeastern England was not directly related to the occurrence of phytophagous mites. Chant (1959a) also observed that T. pyri increased on apple trees in the absence of phytophagous mites. In surveys of mite populations, McMurtry and Johnson (1965) found that A. hibisci often attained its highest population density in the spring or early summer when mite prey densities were very low. They also found that rapid increases of this phytoseiid followed the beginning of blossoming and that its egg production peaks were closely correlated with peaks in flowering intensity. In one orchard, A. hibisci populations reached unusually high levels, apparently as a result of large quantities of pollen drifting from adjacent plants of Ricinus communis L. These findings strongly suggest the use of pollen by A. hibisci for reproduction. Thus it may be said that many phytoseiids are non-specific facultative predators. From the results of the present study, T. mcgregori falls in this category and is therefore somewhat independent from the influence of prey density while T. occidentalis appears to be very dependent on mites for food. Both of these phytoseiids seem to be well adjusted to their environment in the untreated orchards in Cache Valley. Chant (1959a) also found phytoseiids in southeastern England to be well adjusted to their environment.

In the treated orchards, the populations of the phytophagous mites were higher than those of the phytoseiids. This situation was much pronounced in Treated Orchard No. 1 during 1966. The population densities of the phytophagous mites were also much higher in the treated orchards than in the untreated orchards. Late in the season there were frequently more phytoseiids in the treated orchards, but they apparently came too late to suppress the spider mites.

A number of factors may explain the greater numbers of phytophagous mites in the treated orchards than in the untreated orchards. One is that the suppression of the phytoseiid populations by pesticides limits their effectiveness as predators. The greater numbers of phytoseiids on the untreated leaves help to limit the number of phytophagous mites in the untreated orchards. Secondly, the foliage of the untreated orchards was often diseased and had many dead areas. These leaves may not have been as attractive to the phytophagous mites as the clean and healthy leaves of the treated orchards. Gilliat (1935) also observed in Nova Scotia that Panonychus ulmi flourished better in treated orchards than in untreated ones. Poor spraying during 1966 in the Treated Orchard No. 1 was also in part responsible for the great abundance of phytophagous mites that occurred in that orchard.

The phytoseiids in the treated orchards showed no evidence of effectively controlling the phytophagous mites, which often increased to high levels. There was also no evidence that T. mcgregori could increase its numbers in the presence of the large numbers of mite prey. There was, however, an increase in the numbers of T. occidentalis in the treated orchards where greater numbers of prey mites were present.

The failure of T. mcgregori to control the phytophagous mites and its lack of build-up in the presence of spider mites, strongly indicates the acceptance of food material other than mite prey. This failure may also be due in part to a disparity between the reproductive rates of the phytoseiids and the phytophagous mites and a low feeding capacity on the part of the predators. Chant (1961a) also observed in southeastern England the failure of a number of phytoseiids to control other species of mites. He believed that phytoseiids, with the possible exception of A. hibisci, were of little actual or potential value in the control of orchard-inhabiting phytophagous mites in southeastern England.

In contrast to the findings of the present study and to those of Chant, however, various workers have reported successful control of phytophagous mites by phytoseiids. Huffaker and Kennett (1953) found that when not inhibited by parathion, Typhlodromus reticulatus and Amblyseius cucumeris effectively controlled the cyclamen mite in third- and fourth-year strawberry fields in California. Collyer (1958) showed that *T. tiliae* and *A. hibisci* could hold *P. ulmi* in check under certain conditions, whereas other species of *Typhlodromus* and *Phytoseius macropilis* (Banks) were relatively ineffective. Chant (1961b) observed in a greenhouse study that *Phytoseiulus persimilis* successfully controlled *Tetranychus urticae*, while Lee (1966) found in laboratory and greenhouse experiments that *T. occidentalis* was effective in the control of spider mites.

The relatively small number of *Typhlodromus* collected from the litter and soil indicates that these mites do not favor the soil as a habitat. Most of the phytoseiids obtained from the soil and litter were *Amblyseius cucumeris*. This species was not collected on the foliage, and only occasionally under bark. Chant (1959a) obtained only two mites from more than 300 soil samples. Both were *P. macropilis*.

The bark samples seem less suitable than the leaf samples for following the population trends of mites during the summer. There tended to be more variation in the numbers of mites collected from the bark and this, I think, obscured the true seasonal changes in the mite populations in the bark. The variations in the numbers of mites suggest that mites are not uniformly distributed under the bark. The method which was followed to collect mites from apple bark seems to be only suited for qualitative investigations on mites and a better method for studying trends of mite populations under bark is needed. Another drawback for the use of bark samples for population studies is that successive removal of samples tends to deplete the bark on the trees. This problem is more serious in treated orchards where the amount of bark is usually less than in untreated orchards.

Data from the present study show no statistical difference in the efficiencies of the mite brushing machine and Berlese funnels in removing mites from apple leaves.

In conclusion, this study indicates that *Typhlodromus mcgregori* is a non-specific predator of phytophagous mites. *T. mcgregori* is adversely affected by standard pesticide practices, but *T. occidentalis* survives in larger numbers. The two phytoseiids showed no indication of being able to control the high numbers of phytophagous mites which occurred in the treated orchards during late summer.

SUMMARY

Phytoseiid mites are of economic interest because they prey on phytophagous mite pests of crops. The present study, related to the integrated control of orchard-inhabiting phytophagous mites in Utah, was a comparative study of two well-cultivated and regularly sprayed orchards with two unsprayed orchards, located in Cache Valley, northern Utah. The species of phytoseiids, their relative abundance and relationship with phytophagous mites were studied in each orchard.

Two species of phytoseiids, *Typhlodromus mcgregori* Chant and *T. occidentalis* Nesbitt were observed on the foliage, under the bark, and very occasionally in the litter and soil samples. *Amblyseius cucumeris* (Oudemans) was in the soil and litter samples and occasionally under bark. *T. mcgregori* was the dominant phytoseiid mite in the unsprayed orchards, and *T. occidentalis* in the sprayed. The two-spotted mite, *Tetranychus urticae* Koch was the major phytophagous mite observed. Other phytophagous mites observed were the brown mite, *Bryobia rubrioculus* (Scheuten), the European red mite, *Panonychus ulmi* (Koch), and the McDaniel mite, *Tetranychus mcdanieli* McGregor.

The results of the study suggest that *T. mcgregori* is a non-specific facultative predator of phytophagous mites. *T. mcgregori* was susceptible to the pesticide sprays, but *T. occidentalis* presumably had some resistance to the pesticides. In the untreated orchards, the phytoseiids seem to be well adjusted to their environment and to contribute to the low phytophagous mite populations in those orchards. In the treated orchards, however, the phytoseiid mites failed to control the relatively high populations of phytophagous mites which developed.

Comparison of the mite brushing machine and Berlese funnels gave no statistical differences between the efficiencies of these methods in removing either phytoseiid or phytophagous mites from apple leaves, although the brushing machine appeared somewhat superior for the phytoseiids.

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