The Influence of Spray Programs on the Fauna of Apple Orchards in Nova Scotia. III. Mites and their Predators[1]

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Introduction

The commercial production of apples has led growers to greater reliance on chemical control measures for pests than have most fields of agricultural production. Since the turn of the century orchardists have plunged deeper and deeper into artificial measures to produce fruit free from blemishes without greatly alleviating the over-all pest problem and, in some cases, actually producing conditions conducive to still greater problems.

The failure of entomologists to consider the latent effects of sprays on the fauna of the orchard, even though the immediate effects against a particular pest may have appeared desirable, was criticized by Pickett *et al.* (9). They expressed the belief that a very large factor in the increasing damage from insect pests is the disturbance created, by chemical control measures, in the relative balance between pests and their natural enemies. Experimental evidence that this was true with the oystershell scale, *Lepidosaphes ulmi* (L.), was presented in a previous paper by the author (3) in which it was demonstrated that the natural enemies of the scale were destroyed by the sulphur sprays applied for the control of apple scab, *Venturia inequalis* Wint.

Complementary to other portions of the long-term studies on the effects of sprays on the fauna of apple orchards were studies initiated in 1944 on the mite fauna and on the insect predators of mites. The European red mite, *Metatetranychus ulmi* (Koch) [=*Paratetranychus pilosus* (C. & F.)], the clover mite, *Bryobia praetiosa* Koch, and the predators of both of these species, because of their economic importance, have received much more attention than the saprophytic and incidental bark-inhabiting species. The latter have, however, been kept under observation in the search for possible future pests and because they may be important as a measure of the general balance of species in the orchard economy.

A large number of species is involved and our knowledge of their biology and interactions is scanty. A good deal of exploratory work was therefore required. A large fund of information of a general nature on the life histories, habits, and food requirements of a number of important species has been gathered, but detailed ecological research on many of the species becomes increasingly important as the story unfolds. At the present stage a general knowledge of all the species existing in the orchards and of the role played by each in an environment modified by various spray practices is of practical economic value and of basic importance in the organization of more intensified studies on the important species. The studies have been confined to mites and their predators, but since in nature these species are only a part of the biological complex, the relationships of the predators to other species demand investigation.

Methods

Because a multiplicity of ecological factors determines the population densities of the various species in an orchard at a given moment, a spray material interjected into the environment may have a differential effect upon each species. It may be a catastrophic mortality factor for some species and not for others

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because of the differences in their resistance to the toxic effects of the spray. On the other hand, species susceptible to the spray may be able to escape adverse influences through characteristics in their life-histories and habits. Predators in general are sporadic in occurrence for biological reasons which have nothing to do with the spray used, and consequently great care must be exercised in interpreting the effects of sprays.

Experimental plots are basic to research on the fauna of orchards where the spray is an ecological factor that can be added to the environment at will. However, orchards cannot be found which will, individually, include within their environment all the ecological factors for even one organism. Therefore, the variety of environmental conditions in commercially sprayed orchards, considered collectively, has made observation in them a necessary supplement to the studies in the experimental plots. Conclusions about the effect of each spray material on each species must be drawn conservatively, even after wide observation, since the same result may be due to more than one cause.

Laboratory studies may serve a restricted but useful function in the analysis of the less complex aspects of a problem under more or less controlled conditions. Unidentified species may be reared to maturity for specific determination, the life-histories of the species investigated, the prey consumed per unit of time measured, and other studies of like nature pursued without the complications encountered under natural conditions. The reactions of a predator in the laboratory are, however, no real measure of the role played by the species in the orchard, where a much more dynamic complex of environmental factors determines its density and effectiveness. In the final anlaysis, observations on numerous occasions, together with a summation of the knowledge gathered from all sources, have governed the conclusions with respect to the direct and indirect effects of sprays in the orchard.

A series of applications of the individual fungicides or insecticides in fairly large blocks of orchard is the most practical means of determining which species are affected by the spray and at which stage they are most likely to be affected. Each spray material has been used alone as much as possible, but it was usually necessary, for practical reasons, to combine two or more materials in the spray program. This has been particularly true of the insecticides, since in Nova Scotia a fungicide is needed during certain seasons of the year to preserve the foliage from apple scab.

A technique still largely in the developmental stage involves the single application of individual chemicals to one or two trees known to have certain predators. A measure of their detrimental effect on the predators may be made by counting the predacious species on the leaves before and several times after spraying, or by collecting those which drop on to a unit area after the application.

A method for the accurate estimation of the populations of very active predators in the orchard does not seem to be available. Some workers have used observational methods based upon the numbers seen in a stated time, usually one hour, or other methods of comparison in which the numbers of predators cannot be directly related to the prey population on a similar unit. This weakness was not overcome in the course of the work in Nova Scotia during the past few years. The method utilized during the first year or two was simply that of periodically examining each block of orchard sufficiently long to ascertain which species of predators were abundant or scarce. Later a folding tray, one square yard in area and covered with cotton, was found to be a valuable aid in expanding and speeding up the observations. The tray was held beneath the lower limbs of a tree while they were vigorously tapped by another worker to dislodge predators on to the tray. This technique was particularly useful for very active insects before they acquired wings and before the apples became too large to remain on the trees when the limbs were tapped. On some occasions this method of sampling could be used throughout the season where trees could be found with a small crop.

For the gross sampling of arthropods on a tree, a fast-acting dust was applied to individual trees in each plot. The dust, a mixture of 6 per cent DDT, 10 per cent derris, and 30 per cent pyrethrum, was applied with a small power duster on a calm morning about the time the dew was disappearing. Five cones of heavy paper, the open ends of which totalled approximately 16 square feet, were suspended beneath the tree, and at the bottom end of each of the larger cones a small detachable cone was fastened. This method, like those described above, did not give a statistical measure of the numbers of predators, but it was a valuable aid in determining their relative abundance.

The populations of mites on the leaves could be readily measured by microscopic examinations in the orchard. In this phase of the work the same trees were used throughout the studies, and each season they were periodically sampled. The same trees as those from which the leaf samples were taken were used for the winter records on mite eggs. Leaf samples give a satisfactory representation of the density of the population of the European red mite, of *Iphidulus tiliae* (Oud.), and, to a lesser degree, of *Mediolata novae-scotiae* Nesbitt. The clover mite is not so well represented by leaf samples because of its habit of wandering on to the twigs, where many of the mites pass through the quiescent stages and many of the eggs are laid. A measure of the population of the clover mite based on leaf samples is, therefore, somewhat low but still sufficiently accurate to give a practical measure of the trends in the orchard.

For the winter eggs of the phytophagous mites it has so far been impossible to obtain a sampling unit which will permit the direct comparison of the summer and winter populations of these species. The winter eggs of the red mite and of the clover mite are deposited all over the bark, in groups varying from large numbers on the lower sides of the bases of the main limbs to small numbers in the axils of the small twigs. It is thus impossible to measure, during the winter, the numbers of mite eggs on any unit that is as representative of the tree population as are the leaves. A reasonably comparative measure of the differences between plots may be made, however, by limiting the observations to the axils of twigs up to five or six years in age. A count of the full and empty eggs per axil would be impractical because of the large numbers that would have to be counted to eliminate the effect of the great natural variation. With the number of axils that it would be practical to examine in this way the average amount of predation could be determined, but it would be a poor measure of the average number of eggs laid on each axil. To obtain these data and the average number of eggs surviving after the fall predation, the following system of estimation was used: The axils of 500 to 1000 twigs were examined, and the numbers of normal and of empty eggs were estimated on each axil according to somewhat arbitrary but convenient categories.

Because of the way in which the eggs are scattered along the twigs, it is often difficult to decide on an estimate of the number of eggs. To set some limits, and to obtain as much uniformity as possible, all the eggs around the base of the axil and for one-half of an inch out on the twig were taken as the standard of measurement.

The Relative Importance of the Predacious Arthropoda in the Natural Control of Mites

The economic importance of the European red mite in Nova Scotia has, in these studies, focused more attention upon it and the predacious species important in its control than upon the other mites. The clover mite is at present of no economic importance in commercial orchards, since it is destroyed by the sulphur sprays generally used for the control of apple scab. In those orchards in which iron carbamate (ferric dimethyl dithiocarbamate) or copper fungicides (bordeaux mixture and copper oxychloride sulphate) have been used in the bloom applications in place of sulphur, the clover mite has, in general, been controlled largely through the activities of its natural enemies. The damage to the foliage from attacks of the clover mite is very similar to that caused by the red mite but is usually confined to the leaves near the centres of the trees. The clover mite will need close observation as each new material is introduced into the spray program, since it has the potentialities of a pest if it should survive treatments with materials which destroy its natural enemies.

The two-spotted spider mite, *Tetranychus bimaculatus* Harvey, has never been a pest of apple trees in Nova Scotia, having been found only in small numbers in a few instances in the fall of the year. What is presumably the same species is often very numerous in gardens and sometimes does considerable damage. The observations on this species have been too cursory to permit a conclusion as to its potentialities as a pest of apples in Nova Scotia.

Usually the predacious species prey on both of the important phytophagous species, with certain exceptions to be discussed later. Under the great variety of environmental conditions in orchards a predator that is usually of minor consequence may have an economically significant effect if it is present in sufficient numbers. It frequently happens, too, that a spray material destroys one or more of the effective predators, and then because of the increased density of the mite population less efficient predators may become of considerable importance. With very rare exceptions it has been found that at least several species of predators were preying upon the mites and that no one species could be specified as the controlling agent. A previous account of the predators of the European red mite in Nova Scotia based on observations from 1932 to 1935 was published by the late F. C. Gilliatt (2) in 1935. The reader is referred to that paper for details of the biology and habits of a number of these predators. In the discussion of the predators of mites in the following part of this paper it will be necessary to point out certain discrepancies in Gilliatt's interpretations. He worked entirely alone on the project before ideas with respect to the indirect effects of sprays had crystallized. The writer wishes to express his appreciation of the value of Gilliatt's work as the background to these studies on mites and their predators. A criticism of certain of his interpretations is not intended in any way as a reflection on the quality of his work.

Acari

(a) *Iphidulus tiliae* (Oud.) [=*Typhlodromus tiliae* (Oud.)]

Dr. H. H. J. Nesbitt, Professor of Zoology, Carleton College, Ottawa, while engaged in a study of mites on apple trees in the Annapolis Valley, observed several closely related species of typhlodromids. These had formerly all been confused under the name of *Seiulus pomi* Parrott, but the common one is the species described by Garman (1) as *I. fallacis*. Nesbitt has compared specimens with Oudeman's types and has come to the conclusion that *I. fallacis* is a synonym of *I. tiliae* and that it is by far the most common typhlodromid on apple trees in

Nova Scotia. The results of his studies on the mites of apple trees in Nova Scotia will be published shortly, and in his paper the taxonomy and synonomy of the species related to *I. tiliae* will be discussed in detail. Gilliatt (2) discussed a predacious typhlodromid important in the control of the red mite under the name of *Seiulus pomi* Parrott. It is highly probable that the species which he observed was *I. tiliae*, since Nesbitt's work has shown that this is the common one, and *I. pomi* (Parrott) as described by Garman (1) has not been found in Nova Scotia.

I. tiliae feeds readily on eriophyids and has been observed to seize the active forms of *Tydeus robustus* Banks. It probably feeds on the eggs of most of the mite species and is known to be an important natural enemy of the eggs of the red mite. Nesbitt (6) found in the laboratory that *I. tiliae* would feed on the eggs of the clover mite only under pressure of starvation. This relationship appears to hold under orchard conditions as well, as is indicated in the results (Table XIII) from the Hiltz-South Yarmouth orchard. On the copper-sprayed plot of this orchard small number of *I. tiliae* have been consistently associated with a low density of the European red mite in spite of the presence of moderate numbers of the eggs of the clover mite. Had clover mite eggs been a favoured food of *I. tiliae*, an increase in the numbers of the latter species would have been expected and a greater control of the clover mite attained.

Further observation and field studies have shown clearly that Gilliatt (2) was in error about the adverse effect of bordeaux mixture on *I. tiliae*. Although his tests in the laboratory had apparently shown that bordeaux destroyed these mites, the method of testing was evidently not representative of field conditions.

Furthermore, in his discussion of the plots at Berwick in 1931 Gilliatt showed that there were more red mites in the "bordeaux" plot than in the lime-sulphur plots. In this experiment what he considered a bordeaux plot actually had wettable sulphur sprays in the bloom period to avoid russeting of the fruit. It is now known that the use of sulphur in the bloom period would have destroyed *I. tiliae*. In the experiment, the lime-sulphur sprays in the other plots were presumably sufficiently toxic to the red mite to check its increase. The bordeaux being innocuous to the red mite and the wettable sulphurs having destroyed *I. tiliae*, the increase in the red mite on the so-called bordeaux plot is not surprising.

Gilliatt's appraisal of *I. tiliae* as the most important predator of the European red mite in Nova Scotia appears to be correct. It has been frequently observed that this mite may suddenly increase in numbers in the late summer in orchards which have been sprayed with materials detrimental to it, such as sulphur or iron carbamate. This increase often takes place too abruptly to be accounted for by simple biological increase; it seems much more indicative of a movement of the species from the ground or low-growing plants.

The writer believes that much of the predation on winter eggs of the red mite which Gilliatt attributed to *I. tiliae* may have been due to the predacious thrips *Haplothrips faurei* Hood, as has certainly been the case since the present studies were initiated. Gilliatt had rated this thrips as of minor consequence but stated that he had observed it in late August and early September. Actually, in sulphur-sprayed orchards, it is very active late in September and through October.

The adverse effect of flotation sulphur on *I. tiliae* is illustrated in Tables XIII and XV. Very strong additional evidence is deduced from the extreme scarcity of *I. tiliae* in a large number of sulphur-sprayed commercial orchards despite the fact that its favoured prey, the red mite, was moderately numerous in most of these orchards. Iron carbamate acts in much the same way as sulphur on populations of *I. tiliae*, as was shown in the Sutton, Palmer, and Wolfe orchards (Tables XVI, XVIII, and XIX), in which iron carbamate was used in the spray program. In a test at the Experimental Station, Kentville, N.S., summer oil at the rate of 1 gallon to 100 gallons of spray was very detrimental to *I. tiliae* (Table 1). There has been no opportunity to supplement this test with observations on larger blocks of orchard where an oil application was required to control the red mite. The scarcity of *I. tiliae* was in most instances due to spray materials applied for other purposes, and the small numbers of this predator were very probably an important factor contributing to the need for supplementary measures to control the red mite. Lead arsenate (Table IV) and synthetic cryolite (Tables I and IV) in small, single-application tests had no detrimental effect on *I. tiliae*, and the results from the copper-sprayed plot of the Hiltz-South Yarmouth orchard lend confirmatory evidence. In the Hiltz-South Yarmouth orchard both lead arsenate and synthetic cryolite were used in the post-blossom applications without any apparently adverse effect on *I. tiliae*. The only information on the effects of nicotine on *I. tiliae* is that contained in the results from the small-scale tests presented in Tables I, II, and IV. Fixed nicotine appears to have little if any repressive effect, but nicotine sulphate seems somewhat detrimental to the *I. tiliae* population. In all instances in which DDT has been used on an extensive scale in larger blocks of orchard it has been incorporated into sprays or has followed sprays such as sulphur or iron carbamate which are detrimental to *I. tiliae*, and it has, therefore, been necessary to rely on the results of small tests. A single application of DDT was very destructive to *I. tiliae* in these tests, as shown in Tables II, III, and IV. Phygon (Dichloronaphthoquinone), which has been under test as a fungicide, appears to have delayed detrimental effect upon *I. tiliae* (Table V) after a single application. Officers of the Dominion Laboratory of Plant Pathology at Kentville have treated an experimental plot with five applications of this material each year for the past three years, and during that time very few *I. tiliae* have been found during the spraying season.

Table I

I. TILIAE *on Starking leaves from trees in the Variety block at the Dominion Experimental Station, Kentville, N.S., sprayed on August 27, 1947.*

Materials per 100 gal.	*I. tiliae* per 100 leaves	
	Sept. 2	*Sept. 8*
Flotation sulphur, 15 lb.	53	60
Wettable sulphur, 8 lb.	114	60
Summer oil, 1 gal.	4	12
Synthetic cryolite, 4 lb.	111	226
Fixed nicotine,* 4 lb.	235	276
Water-sprayed check	257	352
Unsprayed check	116	284

* Black Leaf 155.

(b) *Mediolata novae-scotiae* Nesbitt

This mite, described by Nesbitt (5) as a new species in 1946, is one of the more important predators of the clover mite, but it does not appear to be capable of keeping the clover mite in check unless aided by other predacious species. *M. novae-scotiae* is a sluggish species, lemon-yellow in colour but characteristically appearing orange to red when it has been feeding on clover mite eggs. Apparently *M. novae-scotiae* does not feed readily, if at all, on red mite eggs in the orchard; but it will seize eriophyids and the mite *Czenspinskia lordi* Nesbitt, a feeder on fungal mycelia found only on trees that have not been sprayed for several years. Even though common on completely neglected

TABLE II.

I. TILIAE *on Stark leaves from trees in the G. West orchard, sprayed on August 15, 1948.*

Materials per 100 gal.	*I. tiliae* per 50 leaves		
	Just before spraying	Aug. 19	Sept. 10
Check (1st tree)	—	58	88
Check (2nd tree)	—	69	101
Check (3rd tree)	—	63	—
DDT, 2 lb. (50%) (1st tree)	73	4	1
DDT, 2 lb. (50%) (2nd tree)	—	2	—
Nicotine sulphate, 1 pt. (1st tree)	94	11	43
Nicotine sulphate, 1 pt. (2nd tree)	—	4	30
Fixed nicotine, 4 lb. (1st tree)	71	39	51
Fixed nicotine, 4 lb. (2nd tree)	—	69	59

TABLE III

I. TILIAE *on the leaves of DDT-sprayed trees in the Drew Orchard and the Hiltz-South Yarmouth Orchard, 1944.*

	I. tiliae per 50 leaves	
	Just before spraying	A few days after spraying
McIntosh—Drew Orchard	33	0
Stark—Hiltz-South Yarmouth Orchard	16	0
Gravenstein—Hiltz-South Yarmouth Orchard	50	0
Stark Check—Hiltz-South Yarmouth Orchard	14	6
Gravenstein Check—Hiltz-South Yarmouth Orchard	6	7

McIntosh sprayed in Drew orchard on July 12.
Stark in Hiltz-South Yarmouth orchard sprayed on July 24.
Gravenstein in Hiltz South-Yarmouth orchard sprayed on August 1.

TABLE IV

I. TILIAE *on Ben Davis and Gravenstein leaves from trees in the South Sawler Orchard, sprayed on July 23, 1948.*

Materials per 100 gal.	Average *I. tiliae* per 50 leaves			
	Aug. 2	Aug. 9	Aug. 23	Sept. 13
Check	32	—	67	56
Nicotine sulphate, 1 pt.	4	15	20	36
DDT, 2 lb. (50%)	0	0	1	13
Lead arsenate, 4 lb.	15	21	27	36
Synthetic cryolite, 4 lb.	30	75	65	66

TABLE V.

I. TILIAE *on Gravenstein leaves from trees in the South Sawler Orchard, sprayed on August 2, 1948.*

Materials per 100 gal.	*I. tiliae* per 50 leaves				
	Before spraying	Aug. 4	Aug. 10	Aug. 23	Sept. 13
Check	37	—	34	—	56
Phygon, 1 lb. (1st tree)	—	42	12	8	2
Phygon, 1 lb. (2nd tree)	—	32	15	4	4

trees, *M. novae-scotiae* has not been seen in large numbers on these. In the few orchards in which *M. novae-scotiae* has been present in fairly large numbers, the only fungicides used were copper fungicides (Tables XIII and XV). There are as yet some unexplained differences in the natural control of the clover mite on completely neglected and on copper-sprayed trees, the clover mite always being more numerous on the copper-treated trees than on the neglected ones. With this increase in the population of the clover mite there is also an increase in the predacious mite *M. novae-scotiae*, which feeds on clover mite eggs. Even with increased numbers of *M. novae-scotiae* the clover mite maintains a higher level of population on the copper-sprayed trees than on neglected trees. The data in Tables XIII and XV indicate that flotation sulphur destroys this predacious species, but more evidence is needed, since the sulphur appears to destroy the only two species found in sprayed orchards upon which it is known to prey. Wide observation and the results in Tables XIV, XVI, XVII, XVIII, and XIX demonstrate that iron carbamate is very detrimental to this species. Lead arsenate and synthetic cryolite are innocuous to *M. novae-scotiae*, since both materials were used in the codling moth control sprays in the Hiltz-South Yarmouth plots with no repressive effect on the population of *M. novae-scotiae* (Table XIII). Very little information as to the effects of the other spray materials on this mite is yet available.

(c) *Anystis agilis* Banks

This is a large, very active, crimson-coloured, predacious mite which preys upon a large number of species of mites and small insects. Since chance encounter seems to govern its search for food, it seems likely that its value in the control of any one species depends upon the numerical relationships of all the species upon which it feeds; that is to say, it feeds most often upon the species it encounters most frequently. Nothing is known as yet about its preferences in prey, and these preferences, if any, will modify the effects due to chance encounter. Table VI shows that iron carbamate and copper fungicides have little if any effect upon these mites but that the addition of lead arsenate to the iron carbamate is very detrimental. Iron carbamate with and without lead arsenate was tested in the North Sawler Orchard (see later description) and it is possible that the greater populations of red mite and clover mite (Table XIV) where the lead arsenate was used were due in part to the destruction of *A. agilis.* Nesbitt (6) has shown that there are two generations of this mite each year, the eggs being laid on the ground and the larvae moving back to the apple trees. This habit probably enabled them partially to escape the effect of sodium dinitro-o-cresylate in the Boyle orchard (Table VI) and has enabled them to become more numerous in the late summer where other detrimental materials have been

TABLE VI

A. AGILIS *per Ben Davis tree in the Aldershot orchards after dusting with a fast-acting dust (5 trays per tree or 16 sq. ft.)*

Date	Iron carbamate	Iron carbamate and arsenic	Sulphur	Copper	Iron carbamate and DNC*
			1945		
Aug. 28	74	1	0	268	0
Sept. 6	30	39	—	—	—
			1946		
May 28	17	7	0	0	0
June 25	17	0	0	11	0
July 4	56	0	0	1	3
Aug. 9	15	3	0	5	13
Aug. 31	48	2	0	4	0
			1947		
May 27	0	0	0	0	0
June 21	0	0	0	0	0
July 17	3	0	0	0	0
Aug. 2	48	0	0	0	0
Aug. 28	34	0	0	4	0
			1948		
June 17	0	0	0	0	0
July 13	7	0	0	2	1
Aug. 11	43	2	0	48	13

*Sodium dinitro-o-cresylate as a dormant treatment in 1945, 1946, and 1948.

TABLE VII

A. AGILIS *per tray (1 sq. yd.) in the Aldershot orchards in 1948 after tapping the lower limbs of Ben Davis trees to dislodge the predators.*

Date	Iron carbamate	Iron carbamate and arsenic	Sulphur	Copper	Iron carbamate and DNC
May 20	0	0	0	—	0
June 1	6	0	0	0	0
June 22	14	—	11	1	—
July 20	23	0	1	31	85
Aug. 4	14	2	2	35	6
Sept. 15	92	0	6	27	—

used in the spray program. There is evidence from Table VI that flotation sulphur destroys or repels these mites, since the presence of large numbers of red mites should have provided ample food (Table XV). The extreme scarcity of *A. agilis* in commercial orchards is probably due to their repression by the arsenicals and possibly also by the sulphur sprays. There is some evidence, not as yet confirmed, that synthetic cryolite and nicotine sulphate are not severely detrimental to *A. agilis.*

(d) *Other Acari*

In orchards which have not been sprayed or subjected to cultural treatment for several years there are a number of predacious species which are rarely found in orchards treated for commercial production. These species include such forms as *Eupalus parvus* Ewing, *Eupalus biscutum* Nesbitt, *Cunaxa* sp., *Cyta latirostris* Herm., *Atomus* sp., mites of the Phytoseiinae group, and probably others. There are also numerous bark-inhabiting species of no known importance. The predacious mite *Hemisarcoptes malus* (Shimer), important in the control of the oystershell scale, has been discussed in a previous paper (3).

Araneae

Several small species of spiders have been observed to seize the active forms of the European red mite, but where there is a dense population of the mites the spiders have been of very minor importance. Under the more natural conditions of uncared-for orchards in which the red mite population is normally at a very low level, spiders may possibly be more important in the maintenance of a low density of the mites. Observations have been made on the numbers of spiders in the experimental plots, but it has not been possible as yet to demonstrate that any of the commonly used spray materials are toxic to spiders.

Thysanoptera

(a) *Haplothrips faurei* Hood

Under the conditions of the current commercial spray practices, whereby the density of the European red mite is usually much above the natural level, the thrips *Haplothrips faurei* Hood is one of the most important factors in the natural control of the red mite. Sulphur appears to have the property of repelling or destroying *H. faurei*, but, although the thrips may be scarce in the early summer, it is usually abundant in the late fall in those orchards with a high population of red mites. The possible confusion by Gilliatt (2) of its work with that of *I. tiliae* in the late fall has already been discussed. The large numbers of thrips found in association with large numbers of red mite eggs in the fall appear to be due to the tendencies of the thrips to disperse and to the attraction of large numbers of red mite eggs. This infiltration of the thrips is not, however, limited to the fall, as the thrips may become plentiful at any time during the growing season if the density of the red mite is sufficiently great and no deterrent material, such as sulphur, is in use. This thrips may also be present in smaller numbers under favourable spray conditions even when there are only a few mites. Though the occurrence of *I. tiliae* under favourable conditions appears to be almost inevitable, the numbers of *H. faurei* under the same circumstances are much more sporadic.

MacPhee (4) found that there were three generations of this thrips each year although there appeared to be great overlapping of generations. The winter is spent in the adult stage but the adults have never been found on apple trees in winter.

This thrips also feeds readily on clover mite eggs and is probably a general feeder on mite and insect eggs. In the laboratory MacPhee found that it would feed readily on eggs of the eye-spotted bud moth, *Spilonota ocellana* (D. & S.).

TABLE VIII

H. FAUREI *per tray (1 sq. yd.) after tapping the lower limbs of Starking trees in the Tobin orchard and of King trees in the Sutton orchard.*

Tobin: bordeaux — iron carbamate with nicotine sulphate.
Sutton: bordeaux — iron carbamate with lead arsenate.

Date of sampling	Sutton orchard		Tobin orchard	
1947				
June 20	–	Red mite and clover mite fairly heavy, becoming light.	21	Red mite rather heavy, becoming light.
July 4	–		41	
July 16	41		–	
July 23	155		–	
July 29	144		158	
Aug. 13	50		111	
Sept. 9	–		65	
Sept. 14	212		119	
Sept. 29	–		98	
Oct. 9	–		40	
1948				
May 28	–	Red mite and clover mite light.	66	Red mite light, increasing somewhat later in season.
June 18	2		23	
July 27	–		0	
Sept. 14	–		33	

TABLE IX

HILTZ-SOUTH YARMOUTH ORCHARD—H. FAUREI *per tray (1 sq. yd.) after tapping the lower limbs of Baldwin trees in the Hiltz-South Yarmouth orchard in 1947.*

Date	Copper	Sulphur	
July 10	34	6	Red mites plentiful on the sulphur plot but not on the copper plot.
July 31	9	2	
Sept. 11	64	168	
Sept. 17	15	245	

It may be that the thrips has no special preference for the eggs of the red mite and that the apparent preference may simply be associated with the mathematical odds in favour of its finding red mite eggs more often. If so, the degree to which the thrips feeds upon the eggs of the predacious mite *I. tiliae* would not be of great economic significance, since the eggs of the latter are always much less numerous than those of the European red mite.

In the Tobin orchard (Table VIII), where nicotine sulphate was used as the insecticide in a bordeaux-iron carbamate spray program, the numerical status of *H. faurei* was evidence that this thrips survived or escaped the effects of nicotine sulphate. A further discussion of the effects of the thrips on the mite population is given in a later section in which the results in the Tobin orchard are examined in more detail.

In 1947 in the Sutton orchard, where lead arsenate was the insecticide in a bordeaux-iron carbamate fungicide program, large numbers of these thrips were associated with a fairly high density of red mite (Table VIII) and decreased as the population of the red mite declined.

Copper fungicides have little if any adverse influence on *H. faurei*, the relatively small numbers on the copper-sprayed plots (Tables IX and X) being

Table X

Aldershot Orchards — H. faurei *per Ben Davis tree in the Aldershot orchards after dusting with with a fast-acting dust. (5 trays per tree or 16 sq. ft.)*

Date	Iron carbamate	Iron carbamate and arsenic	Flotation sulphur	Copper	Iron carbamate and DNC
		1945			
Aug. 28	4	0	0	6	0
Sept. 6	3	0	—	—	—
		1946			
May 28	0	0	2	4	3
June 25	2	3	1	5	4
July 4	0	0	1	4	7
Aug. 9	13	16	14	39	2
Aug. 31	7	10	0	44	0
		1947			
May 27	0	0	1	4	3
June 21	0	4	2	0	1
July 17	2	3	0	28	11
Aug. 2	1	2	10	82	5
Aug. 28	3	15	13	16	48
		1948			
June 17	3	3	0	2	13
July 13	0	5	7	42	18
Aug. 11	5	8	65	160	9

The red mite was abundant in 1947 and 1948 in the sulphur plot and in the iron carbamate plot in which sodium dinitro-o-cresylate (DNC) was used as a dormant spray.

associated with the small numbers of mite eggs. On the sulphur plots the records in the same tables show large numbers of thrips but only after the last sulphur spray had been on the trees for some weeks. It is evident from this experiment and from general experience in commercial orchards treated with sulphur sprays that sulphur is detrimental to *H. faurei.* The only evidence that this thrips is destroyed by DDT was its extreme scarcity in a number of orchards where DDT was incorporated into a bordeaux-iron carbamate program.

(b) *Other predacious thrips*

Several other thrips feed upon red mite eggs and probably also on eggs of the clover mite, the feeding in the latter case having been observed only in the laboratory. These species are *Leptothrips mali* (Fitch), *Zygothrips minutus* Uzel, and *Scolothrips sexmaculatus* (Pergande).

L. mali has been observed in moderately large numbers on several occasions in commercial orchards where bordeaux and iron carbamate fungicides were applied. In these instances a number of other predators were at work, but as no extensive observations were made, their relative value was not determined. In 1948 these thrips were rather numerous in two commercial blocks which received post-blossom applications of nicotine sulphate and fixed nicotine (Black Leaf 155).

Z. minutus has been observed in the act of attacking eggs of the red mite, but this species has been found mainly in those experimental orchards which have received only copper fungicides. Very small numbers have also been seen in a few instances in blocks sprayed with bordeaux and iron carbamate. At present this species is of little economic importance because of its small numbers. It apparently hibernates under flakes of bark on the trunks, where it was found in samples from the Hiltz-South Yarmouth copper-sprayed plot. Examination before and after an unusually cold spell (probably -25°F.) in 1948 indicated that extreme cold destroyed this thrips, since no survivors could be found after the second search although numerous dead specimens were located.

S. sexmaculatus appears to be fairly widely distributed, but has been noted only in very small numbers and for that reason is of little economic significance. It has not been seen by the writer to feed on eggs of the red mite in the orchard, but several workers have referred to it as a predator of the red mite.

(TO BE CONTINUED)