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Dispersal of mites within apple trees of an abandoned orchard in Central Utah

Eugene Eldon Nelson
Brigham Young University - Provo

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DISPERSAL OF MITES WITHIN APPLE TREES OF AN ABANDONED ORCHARD IN CENTRAL UTAH

A Thesis
Presented to the
Department of Zoology and Entomology
Brigham Young University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Eugene E. Nelson
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This thesis by Eugene E. Nelson is accepted in its present form by the Department of Zoology and Entomology of Brigham Young University as satisfying the thesis requirement for the degree of Master of Sciences.

8 May 68
Date

Typed by Carolynn Nelson

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INTRODUCTION

A survey between July, 1965 and November, 1966 of mites in the trees of abandoned apple orchards in central Utah indicated that Bryobia praetiosa Koch, B. rubrioculus (Scheuten), and Typhlodromus mcgregori Chant were the most common mites present. Bryobia praetiosa (clover mite) was the most common species on the trees during the winter, but it was replaced by B. rubrioculus (brown mite) during the summer. Both species are phytophagous and in 1956 were considered to be economically important in Utah apple orchards (Davis, 1956), as well as in other fruit growing areas of the world (Weldon, 1909; Webster, 1912; Venables, 1943; Roesler, 1952). Similarities in the life histories of brown mites and clover mites may allow them to occur together on the trees during certain times of the year. Until 1957 when Bryobia arborea Morgan and Anderson (=rubrioculus) was described, B. rubrioculus and B. praetiosa were even thought to be the same species, but they are now considered distinct species (Anderson and Morgan, 1958; Manson, 1967). If mites referred to as B. praetiosa before 1957 were arboreal in orchard trees and the work was done during the summer months, they are considered to be B. rubrioculus in this review.

Typhlodromus mcgregori was described in 1959 by Chant, and since it is predacious, it may affect the control of clover mites and brown mites. Lord, Herbert, and MacPhee (1958) maintained that Typhlodromus spp. were the most important predators of B. rubrioculus and B. praetiosa in apple orchards of Nova Scotia and could rapidly reduce the phytophagous populations. Discrepancies in relative distributions of predators and prey influence the effectiveness of the predator (Chant, 1959; Chant and Fleschner, 1960); thus a knowledge of dispersion characteristics and distribution patterns of T. mcgregori is necessary before attempting to evaluate its importance as a pest control agent.

To date, the rather limited number of reports on population movements of B. rubrioculus and B. praetiosa are somewhat contradictory, and studies of the dispersion characteristics of T. mcgregori have not been made. Norman H. Anderson, in personal communication with Lord, Herbert, and MacPhee (1958) maintained that B. praetiosa did not migrate from the cover crop into apple trees in British Columbia; however Jorgensen (1966) indicated that in central Utah, B. praetiosa was found in apple trees during the winter. Lienk and Chapman (1951), working in New York, stated that B. rubrioculus spent as much time on the spurs during the summer as it did on the leaves. Roesler (1952) in Germany and Summers and Baker (1952) in California agreed with Lienk and Chapman (1951); they concluded that B. rubrioculus spent the majority of its time on the spurs and moved to the leaves to feed only during favorable periods of the day. But Anderson and Morgan (1958) stated that the only movement of importance in British Columbia occurred when the adult mites crawled to the spurs to lay winter eggs. These scattered reports indicate considerable disagreement concerning dispersion and distribution habits of the clover mites and brown mites.

The objectives of this study were to determine dispersion characteristics and distributions of T. mcgregori, B. rubrioculus, and B. praetiosa, and to determine possible correlation among them. Information of this nature may be important when attempting to evaluate the effectiveness of *T. mcgregori* as a control agent of phytophagous mites during future integrated control programs in central Utah.

METHODS

An abandoned apple orchard with 99 trees was selected at Highland in American Fork, Utah for study, since it had not been treated with pesticides for several years and was known to have large populations of T. mcgregori, B. rubrioculus, and B. praetiosa. Commercial orchards could not be used because the regular spray programs virtually eliminated the three species to be studied.

Sample trees were selected with the aid of a random numbers table so that mite distribution within the orchard could be determined and trees with the largest populations selected for more intensive study. Samples of 100 spurs, each about 2 in. long, were collected from each of 48 randomly selected trees, beginning on February 4, 1967, and ending on February 20, 1967. The same number of spurs was selected from each scaffold limb so that the 100 spur samples were collected without observable bias within the trees.

Ordinary methods (e.g. marking and recapture) used to determine population movements of larger animals could not be used because mites are simply too small to mark and recapture. Consequently, the following methods were developed: (1) trees with the largest density of overwintering mites were selected and plots were established and sampled periodically within them to determine relative changes in distribution. (2) Tree trunks were banded with Tanglefoot[1] in order to determine the

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[1] Tanglefoot Company, Grand Rapids, Michigan.

degree and direction mites move along the trunk. (3) Spurs and their respective leaves were observed to determine movement of *T. mcgregori* and *B. rubrioculus* between spurs and leaves. (4) Field observations of the number of mites per leaf were used to determine the effect of climatic variations upon *B. rubrioculus*. (5) Brown mites were placed on apple seedlings and later counted as mites per leaf to disclose the degree and methods of dispersion.

Plot Sampling. Three trees (No. 10, 23, 83) known to have high numbers of *T. mcgregori* were selected by the random sampling within the orchard and sample plots established within each. A plot is simply a portion of the tree with enough spurs to provide three replicated samples of 100 spurs each. An attempt was also made to select the plots so that two or three were adjacent to one another along the scaffold limbs. Thus, dispersion within the tree could be determined by replicated samples of adjacent plots located along the scaffold limbs. Tree no. 10 had 12 plots, no. 23 had 18 plots, and no. 83 had 11 plots. Each sample was placed in a modified Berlese funnel for 48 hours, and the numbers of all species recorded. Sampling was repeated three times; the first samples were taken between March 1 and 22, 1966, the second between March 24 and April 10, 1966, and the third between June 10 and July 14, 1966. Representative specimens were identified to observe possible species changes among the plots as the season progressed. Changes in their distribution and composition were used to illustrate general population movements. Each sampling was tested for randomness with the Chi-square Goodness of Fit test and then correlation coefficients were determined among the three species to estimate changes in distributions and interactions that may have occurred.

Tanglefoot Strips. Five trees were chosen at random on March 21 and sprayed with a band of white paint one foot high around the trunk. This band was about 2 in. above ground level. Each of the painted areas was then ringed with a 2 in. high strip of Tanglefoot 8 in. above ground level (Fig. 1). Three additional trees were similarly painted and ringed with Tanglefoot on March 9. As the mites crawled over the painted surface or became trapped in the Tanglefoot, they were easily seen against the white background; thus their relative numbers and positions relative to the Tanglefoot strips were conveniently noted. Trapped specimens were collected from the upper and lower edges of the Tanglefoot strip for identification. Live mites adjacent to the Tanglefoot were also collected and identified. The area of the Tanglefoot from which a particular mite was collected was used as an indication of the direction the mite was moving before it was trapped. Mites trapped on the upper edge of the Tanglefoot were assumed to be migrating down the trunk and off of the tree; whereas mites trapped on the lower edge were considered to be moving up the trunk and into the tree from the ground cover.

Sampling of Spurs and their Respective Leaves. Movement of *T. mcgregori* and *B. rubrioculus* between the leaves and spurs was determined during a 24 hour period on July 25-26, 1966 starting at 6 AM. A mite brushing machine was used to remove the mites from leaf and spur samples collected every other hour during the day and night and every hour at dawn and dusk. Samples consisting of 25 spurs per sample were taken from each of five trees as well as five leaves from each spur to obtain leaf samples of 125 leaves each. Leaf and spur samples were then brushed separately to determine the number of *T. mcgregori* and *B. rubrioculus* ineach.

Fig. 1. Base of a tree trunk showing band of white paint and the Tanglefoot strip.

Field Observations. The effect that climatic variations have on the movements of *B. rubriocculus* was observed in the orchard during a 12 hour period on June 22, 1967. Fifteen selected spurs with their respective leaves were examined at hourly intervals. The numbers of brown mites found on the leaves, as well as the weather conditions at the time of observation, were noted. Also a 24 hour study during relatively constant weather conditions was made five days later.

Seedling Infestation Experiment. Field observations and a review of the literature (Lienk and Chapman, 1951; Roesler, 1952; Summers and Baker, 1952; Anderson and Morgan, 1958) suggested the daily movements of *B. rubrioculus* between the leaves and spurs, which led to a study concerning the degree of dispersion from one area to another within the trees. One-hundred brown mites were placed on a single leaf near the center of a mite-free apple seedling to observe possible movements. Two weeks later all of the leaves were examined and the number of mites on each leaf counted.

The main avenues available for mite movement are walking from one point to another, dropping from the leaves, or being dispersed by air currents. Field observations provided data on dispersion by walking, and dispersion either by dropping from the leaves or drifting in air currents was studied in the following experiment. Tanglefoot was placed around the petiole of a single leaf positioned near the center of a 2 ft. high apple seedling on June 20, 1967. The leaf was then infested with 50 adult brown mites. A second seedling of similar size was also used. The main trunk was divided with a piece of white cardboard large enough to obscure the lower leaves while looking down from above. The cardboard barrier was then ringed with Tanglefoot. Fifty adult brown mites were placed upon a single leaf above the cardboard barrier. The leaf's petiole was then ringed with Tanglefoot, thus making escape by walking improbable. Four leaves above and four leaves below the infested leaf were removed 37 days later and the number of mites per leaf counted.

RESULTS

The initial sampling of 48 trees showed that the mites inhabiting the spurs during the winter were mostly T. mcgregori or B. praetiosa with an occasional Tydeid. The average number of T. mcgregori per 100 spurs was 1.19 while B. praetiosa averaged 5.54. Brown mites were absent from 15 of the 48 samples while over one-half of the total (266) were collected from only two samples. Typhlodromus mcgregori was absent from 25 of the samples while three samples contributed 20 of the 57 total. The large percentages found in so few samples suggested a non-random or clumped distribution which was verified by the Chi-square Goodness of Fit test for randomness (T. mcgregori $X^2 = 138.3$, $X^2_{.95(47)} = 64.0$; B. praetiosa $X^2 = 2{,}485$, $X^2_{.95(47)} = 64.0$). There was no correlation between T. mcgregori and B. praetiosa among the trees ($r = .23$).

Plot Sampling. All samples taken from the three trees selected for more intensive study (No. 10, 23, 83) were tested with the Chi-square Goodness of Fit test. The results, with one exception, suggested a non-random distribution within the trees for T. mcgregori, B. praetiosa, and B. rubrioculus (Table 1-3). Typhlodromus mcgregori, collected during the second sampling replication of tree no. 83 (Table 3), was randomly distributed when tested at a P = .95 level, but it too was non-random at the P = .80 level.

The test for correlation within and among replicated samples of T. mcgregori, B. praetiosa, and B. rubrioculus resulted in highly

Table 1. Numbers of mites per sample within tree no. 10, with their corresponding Chi-square values.

Plot Number	Mites per Replicated Sample[a]					
	Typhlodromus mcgregori			*Bryobia praetiosa*		*Bryobia rubrioculus*[b]
	1	2	3	1	2	3
1	4	4	35	1	9	88
2	4	3	28	0	1	142
3	1	13	52	20	1	154
4	24	5	8	2	5	55
5	2	1	10	4	26	56
6	1	8	5	19	146	31
7	0	1	16	1	32	64
8	21	1	40	1	10	53
9	4	5	35	3	0	126
10	4	2	34	2	142	196
11	2	2	39	16	3	104
12	14	2	52	114	12	162
Chi-square[c]	109.0	33.5	98.5	749.7	970.1	445.0

[a] Sample 1 was taken between March 8 and 10, 1967, sample 2 between March 30 and April 3, and sample 3 between June 22 and 28.

[b] *Bryobia rubrioculus* had replaced *B. praetiosa* in the trees by this collection date.

[c] Chi-square value from table; $\underline{X}^2_{.95(11)} = 19.7$.

Table 2. Numbers of mites per sample within tree no. 23, with their corresponding Chi-square values.

Plot Number	Mites per Replicated Sample[a]					
	Typhlodromus mcgregori			*Bryobia praetiosa*		*Bryobia rubrioculus*[b]
	1	2	3	1	2	3
1	3	5	135	1	0	267
2	2	0	127	1	2	213
3	1	1	50	11	2	132
4	0	0	114	13	47	319
5	4	0	159	2	0	391
6	2	1	172	5	24	120
7	5	1	51	2	29	197
8	0	1	57	5	81	413
9	0	0	34	4	1	78
10	1	3	51	60	87	253
11	4	0	53	3	3	352
12	1	0	52	0	10	268
13	0	2	26	30	2	152
14	0	2	51	1	5	173
15	0	0	62	5	13	564
16	2	0	60	3	30	426
17	0	0	99	30	1	329
18	1	0	156	6	57	235
Chi-square[c]	32.0	35.6	389.0	400.5	654.8	994.0

[a] Sample 1 was taken between March 15 and 22, 1967, sample 2 between April 6 and 10, and sample 3 between June 14 and July 14.

[b] *Bryobia rubrioculus* had replaced *B. praetiosa* in the trees by this collection date.

[c] Chi-square value from table; $\underline{X}^2_{.95(17)} = 27.6$.

Table 3. Numbers of mites per sample within tree no. 83, with their corresponding Chi-square values.

Plot Number	Mites per Replicated Sample[a]					
	Typhlodromus mcgregori			*Bryobia praetiosa*		*Bryobia rubrioculus*[b]
	1	2	3	1	2	3
1	0	1	0	0	4	15
2	0	0	0	0	4	16
3	0	3	0	3	55	9
4	0	1	1	21	1	7
5	2	2	10	4	0	44
6	1	3	2	0	1	40
7	2	0	6	29	6	39
8	3	0	1	63	0	21
9	2	5	5	4	0	33
10	10	3	20	7	5	69
11	8	4	18	5	26	89
Chi-square[c]	45.8	15.0	92.6	303.8	308.4	87.0

[a] Sample 1 was taken between March 1 and 4, 1967, sample 2 on March 24, and sample 3 between June 10 and 20.

[b] *Bryobia rubrioculus* had replaced *B. praetiosa* in the trees by this collection date.

[c] Chi-square value from table; $\underline{X}^2_{.95(10)} = 18.3$.

variable coefficients (Table 4). There was rather high positive correlation (.72 and .93) between the first and the third replicated samples of T. mcgregori in trees no. 23 and no. 83, respectively. Correlation was also high (.69 and .93) between T. mcgregori and B. rubrioculus in trees no. 10 and no. 83, respectively. Aside from these, all others were quite low. Representative specimens from the spurs sampled between February 4 and July 14 were mounted on slides and identified. Initially all mites were either adult T. mcgregori or B. praetiosa; however in April several larvae of B. rubrioculus were observed (Fig. 2). After that, the samples were still primarily composed of adult B. praetiosa, but the frequency of B. rubrioculus immatures began to increase. The first B. rubrioculus adults were collected on May 23. Only T. mcgregori and B. rubrioculus were found from June 15 through the remainder of the growing season.

Tanglefoot Strips. Tanglefoot strips girdling the base of several trees provided information concerning the disappearance of B. praetiosa and the appearance of B. rubrioculus. Some of the strips had an equal number of mites trapped on the upper and lower edges; others had a high concentration on the upper edge with relatively few on the lower (Fig. 3), and other strips were just the opposite (Fig. 4). These results suggested population movements both up and down the trunk.

All mites taken from the upper edge were B. praetiosa (Table 5) and those from the lower edge were B. rubrioculus. The majority of live mites collected from the trunk between the Tanglefoot strip and the ground were B. rubrioculus with only a few B. praetiosa. Only eight B. rubrioculus and one B. praetiosa were found in five cover samples collected from 2 to 4 ft. out from the tree base below the Tanglefoot

Table 4. Correlation coefficients for *Typhlodromus mcgregori*, *Bryobia praetiosa*, and *Bryobia rubrioculus* within and among replicated samples of trees no. 10, 23, and 83; winter and spring, 1967.

Correlation Coefficients for Sample Contrasts

Sample Contrasts	Species					
	T. mcgregori			*B. praetiosa*		
	10	23	83	10	23	83
First Sample with Second Sample	-.20	.11	.39	.07	.41	.23
Second Sample with Third Sample	.13	-.03	.46	.01	.19	.01
First Sample with Third Sample	.04	.72	.93	.34	.22	-.17

Correlation Coefficients for the Species Contrasts

Species Contrasts	Samples								
	First Sample			Second Sample			Third Sample		
	10	23	83	10	23	83	10	23	83
T. mcgregori with *B. praetiosa*	.18	-.33	-.01	.05	.09	.30			
T. mcgregori with *B. rubrioculus*							.69	.21	.93

Fig. 2. Relative abundance of _Bryobia praetiosa_ and _Bryobia rubrioculus_ in samples collected between March and July, 1967.

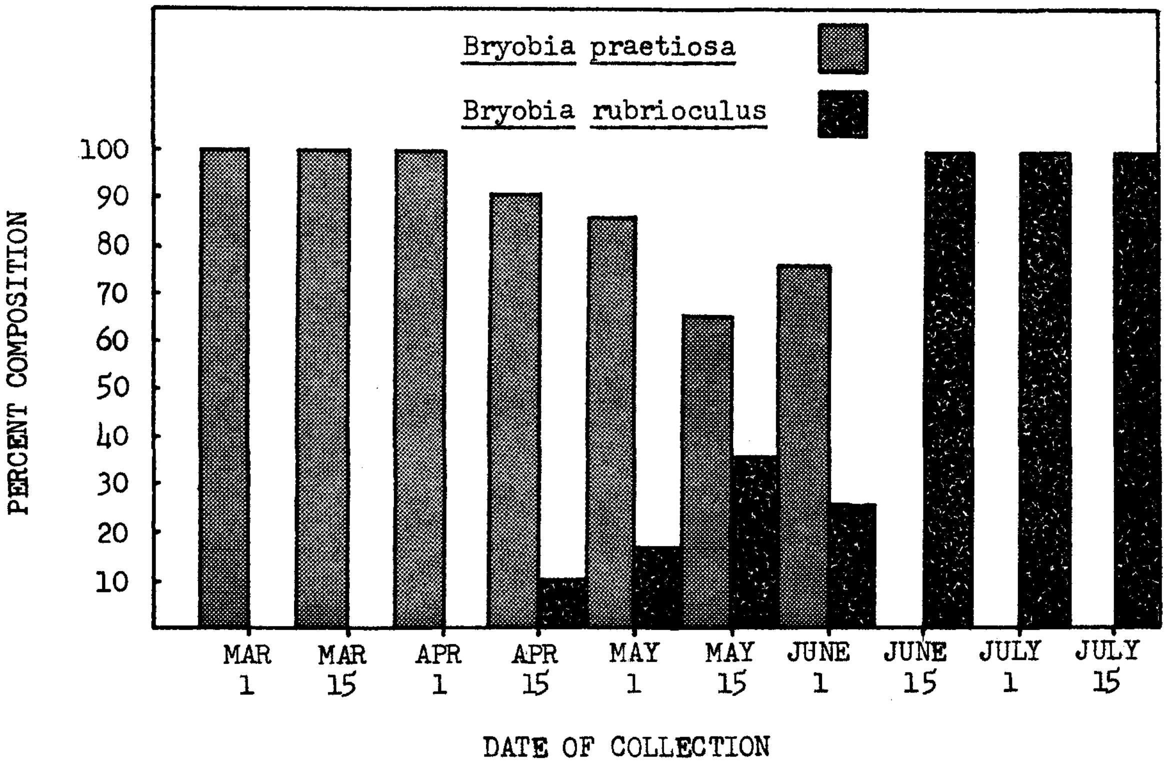

Bryobia praetiosa
Bryobia rubrioculus
100
90
80
70
60
50
40
30
20
10
PERCENT COMPOSITION
MAR 1
MAR 15
APR 1
APR 15
MAY 1
MAY 15
JUNE 1
JUNE 15
JULY 1
JULY 15
DATE OF COLLECTION

Fig. 3. View of a tree trunk base showing mites trapped on the upper edge of the Tanglefoot strip.

Fig. 4. View of a tree trunk base showing mites trapped on the lower edge of the Tanglefoot strip.

Table 5. A comparison of mites collected from and adjacent to the Tanglefoot strips.

Date and species	Mites collected		
	Trapped in Tanglefoot		Collected below Tanglefoot[a]
	Upper edge	Lower edge	
June 7, 1967			
B. praetiosa	16	0	0
B. rubrioculus	0	4	3
June 16, 1967			
B. praetiosa	7	0	18
B. rubrioculus	0	4	9
June 27, 1967[b]			
B. praetiosa			0
B. rubrioculus			55
July 12, 1967			
B. praetiosa	5	0	0
B. rubrioculus	0	13	25

[a] No mites were observed above the Tanglefoot.

[b] No collections were made from Tanglefoot on this date.

strips. These cover samples were collected on July 12.

Sampling of Spurs and their Respective Leaves. Of the 16 leaf samples collected over a 24 hour period, *T. mcgregori* was represented in all except one, but it was absent in 10 of 16 spur samples (Table 6). A total of 640 *T. mcgregori* were removed from all of the leaves sampled and only 70 from the spurs.

Bryobia rubrioculus was more evenly distributed between spur and leaves with 1,220 collected from the leaves and 1,530 removed from the spurs. There appeared to be some correlation between time of day and movement of *B. rubrioculus* between spurs and leaves. Examination of the "difference" column on Table 6 suggests that in midsummer *B. rubrioculus* frequents the leaves most often between 7 PM and midnight and again in the early morning hours.

Field Observations. All *B. rubrioculus* on the leaves of 15 selected spurs were counted each hour for a 24 hour period on June 22, 1967. Two cycles were observed in which there was a gradual increase and subsequent decrease in the numbers of brown mites observed on the leaves. The largest numbers of mites were observed at 6 AM and 9 PM and the smallest at 2 PM and 2 AM (Fig. 5). A 12 hour study was made of the same plots five days later during a period when the weather varied considerably. During periods of relatively calm and sunny weather, the distribution of the mites was essentially the same as the previous study; however if the leaves were disturbed to any extent by wind or rain, the mites quickly moved from the leaves onto the spurs (compare numbers of mites on leaves during constant and variable weather from 3 PM until 7 PM, Fig. 5).

Table 6. A 24 hour comparison of the numbers of Typhlodromus mcgregori and Bryobia rubrioculus on spurs and leaves; July, 1966.

Time	Mites per 125 spurs and 625 leaves					
	Typhlodromus mcgregori			*Bryobia rubrioculus*		
	Leaves	Spurs	Difference	Leaves	Spurs	Difference
6AM	50	0	+50	130	50	+80
7	50	10	+40	80	90	-10
8	50	10	+40			
9	100	10	+90	130	150	-20
10						
11	40	0	+40	80	230	-150
12 Noon						
1	20	0	+20	50	190	-140
2						
3	50	0	+50	60	150	-90
4						
5	70	0	+70	70	70	0
6	50	0	+50	50	130	-80
7	50	0	+50	90	50	+40
8	50	10	+40	150	50	+100
9						
10	10	0	+10	90	90	0
11						
12 Midnight	0	0	0	110	60	+50
1 AM						
2	20	10	+10	40	80	-40
3						
4	10	0	+10	30	40	-10
5	20	20	0	60	100	-40
Totals	640	70	+570	1220	1530	-310

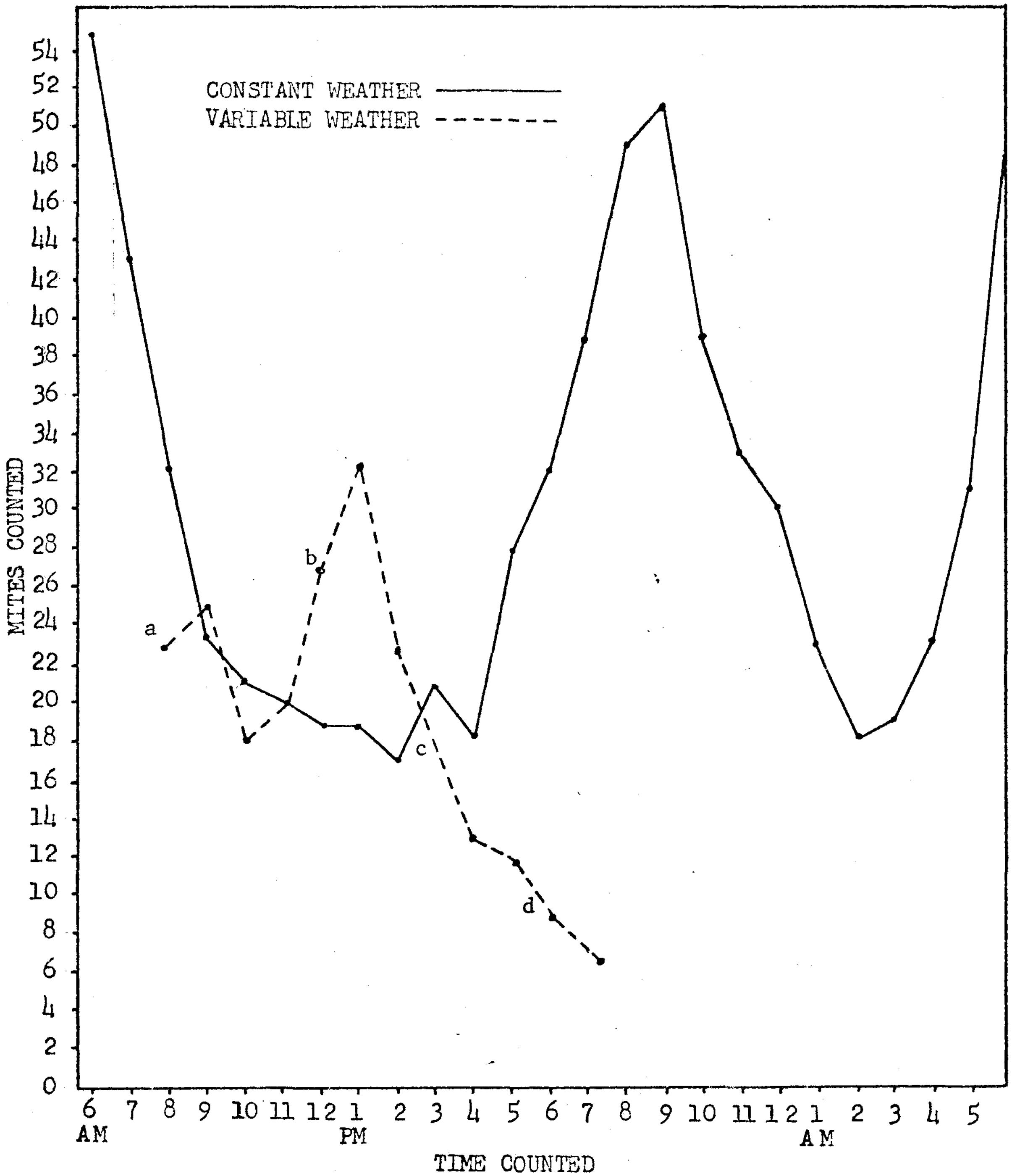
Fig. 5. An hourly comparison of numbers of *Bryobia rubrioculus* found on the same leaves during constant and variable weather conditions; summer 1967.

[a] 8 AM until 12 noon, overcast with intermittant light rain.

[b] 12 noon until 3 PM, sun shined continuously.

[c] 3 PM until 5 PM, sky overcast but no rain.

[d] 6 PM intermittant heavy rain with moderate wind.


CONSTANT WEATHER
VARIABLE WEATHER
MITES COUNTED
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
a
b
c
d
6 AM
7
8
9
10
11
12
1 PM
2
3
4
5
6
7
8
9
10
11
12
1 AM
2
3
4
5
TIME COUNTED

Seedling Infestation Experiment. A leaf near the center of a small apple seedling was infested with 100 adult brown mites on June 7, 1967, and within two weeks the mites had dispersed throughout the entire seedling, but the greatest concentration remained near the point of infestation.

On June 20, 50 adult brown mites were placed on a single leaf (whose petiole had been ringed with Tanglefoot) which was immediately above a white cardboard barrier. Soon after the mites had been placed on the leaf, several dropped onto the cardboard barrier and became trapped in the Tanglefoot. Twenty-four hours later, 31 of the original 50 remained on the leaf, but after 48 hours only 13 remained. Thirty-seven days later there were 110 mites on the four leaves above the cardboard barrier while the four leaves below it had only 18. Another seedling that had been similarly treated, except there was no cardboard barrier, had 89 mites on the four leaves immediately above the infested leaf and 244 mites on the four leaves immediately below it.

DISCUSSION AND CONCLUSIONS

A survey of an abandoned orchard at Highland in American Fork, Utah, was made in January 1967 to determine the relative numbers of the overwintering mites present and their distribution within the orchard. *Typhlodromus mcgregori* and *B. praetiosa* were the most common species inhabiting the trees in this orchard during the winter, but their distribution was apparently clumped since some trees had high numbers of mites present whereas others had rather low numbers. There was no apparent reason for the clumped distribution, nor was there any correlation between mite densities and the relative location of the trees in the orchard. The distribution of the clumps would have to be understood before the reasons for clumping would be evident, and this study does not provide that type of data.

Bryobia praetiosa. Anderson and Morgan (1958) stated that *B. praetiosa* never invaded apple trees in British Columbia (except near the base for overwintering), but in central Utah winter samples of bark and spurs contained substantial numbers of brown mites. The winter samples consisting of 100 spurs had as many as 146 *B. praetiosa* per sample; thus the spurs must provide favorable hibernacula for clover mites.

When *B. praetiosa* migrated into the trees during the fall, they concentrated on the spurs of the peripheral branches where they aggregated much more on some spurs than others. The Chi-square Goodness of Fit test for randomness suggested that hibernating *B. praetiosa* were clumped within the trees. Low correlation coefficients were obtained when analyzing replicated samples within the trees (Table 4). Low or negative correlation coefficients result from small values of one series being associated with large values of another series or large values of one series being associated with small values of another (Croxton, 1959). This is interpreted to mean that those plots with low numbers of brown mites during the first sampling did not have low numbers when the second samples were taken, and conversely, the plots with large numbers during the first sampling did not have large numbers the second sampling. Thus, the low _r_ values indicated that some change in distribution had occurred between sample dates during the winter although movement was not observed in the field, nor was the change described.

Bryobia rubrioculus. Anderson and Morgan (1958) reported that the only movement of _B. rubrioculus_ adults was between leaves and spurs, and since this species was never found on scaffold limbs or tree trunks, they concluded that brown mites never move down the trunk to the ground. The Utah mites varied from this considerably since adults and larvae were collected alive below the Tanglefoot and also from the lower edge of the Tanglefoot in the spring. All specimens collected from the lower edge of the Tanglefoot were _B. rubrioculus_, and some trees had several hundred mites trapped per linear inch of Tanglefoot (Fig. 4, Table 5). Since _B. rubrioculus_ overwinters in the egg stage (Anderson and Morgan, 1958) and the Tanglefoot was placed on the trunk prior to hatching, these data indicate that _B. rubrioculus_ must have deposited winter eggs at almost ground level on the tree trunks or perhaps even on the cover. When the eggs hatched the following spring, the mites became trapped in the lower edges of the Tanglefoot while attempting to move up the tree.

Cover samples taken during the summer near the base of the tree contained eight brown mites, indicating that few B. rubrioculus are in the cover during the summer. Since they readily drop from the leaves, these few mites may have dropped from the tree.

The apparent difference between this study and the findings of Anderson and Morgan (1958) may be explained with some speculation by Pritchard and Baker (1955). They felt that the many subspecies within the whole Praetiosa complex might result from their parthenogenic reproduction. In this case a single mutation could give rise to a local population that differs somewhat from the parent, at least with regard to host relationship, biological development, and minor morphological characters.

Dispersion of B. rubrioculus within the tree by walking was substantiated by field observations, while dispersion by dropping from the leaves or drifting with air currents was demonstrated with experimentation. Brown mites that had been placed on one leaf, whose petiole had been ringed with Tanglefoot, dispersed throughout the seedling within a two week period. Since it is improbable that the mites escaped across the Tanglefoot by crawling, the only methods available for dispersion were dropping from the leaf or drifting with air currents. Fleschner et al. (1956) found that spider mites frequently spin down from the leaf on a silken thread until air currents carry them away. This behavior was not observed among brown mites. They merely moved to the periphery or the lower surface of the leaf and dropped off. Thirteen of 50 mites still remained on the leaf they were placed on at the end of 48 hours, showing that 37 had dropped. Most of the mites dispersed downward by dropping, but some moved laterally and upward, most likely with air currents.

Jorgensen (1964), reported that in Hood River, Oregon, summer brown mites did not migrate between spurs and leaves; thus, his findings agree with Anderson and Morgan (1958) who worked in British Columbia. The present study suggests that there is considerable movement of *B. rubrioculus* between leaves and spurs each day in central Utah. Although the number of mites on spurs and leaves is about equal, there appears to be some correlation between time of day and relative numbers of mites found on leaves and spurs (Fig. 5). During the morning and evening hours *B. rubrioculus* seems to move onto the leaves but retreats back to the spur during the hottest part of the day and the early morning hours. These observations agree with Roesler (1952), and Summers and Baker (1952), who also found that *B. rubrioculus* spends the majority of its time on the spurs and moves to the leaves to feed during favorable periods of the day. This movement is influenced greatly by changing climatic conditions during the hours of most intensive activity on the leaves. It appears that *B. rubrioculus* favored the leaves during cool times of the day when the sun was shining and moved onto the spurs when disturbed by wind or rain.

Interaction between Bryobia praetiosa and Bryobia rubrioculus. *Bryobia rubrioculus* overwintered as eggs in central Utah. Therefore, *B. praetiosa* was the only free-living *Bryobia* on the trees during the winter until April 10 when larvae and nymphs of *B. rubrioculus* were collected. From April 10 to June 15 the percentage of clover mites to brown mites decreased until clover mites were no longer present (Fig. 2). The large numbers of mites trapped in Tanglefoot strips at the base of several trees suggested migration of mites out of, as well as into, the trees after March 21 when the first Tanglefoot was applied (Fig. 3 and 4).

Bryobia praetiosa appeared to move into the trees with the approach of cold weather to overwinter and then moved back onto the cover in the spring. The overwintered eggs of B. rubrioculus that were on the tree trunk, limbs, and spurs hatched in the spring and the resulting mites completely replaced B. praetiosa in the trees by late spring.

Typhlodromus mcgregori. Leetham (1966) sampled cover beneath trees, bark, and spurs during the winter and found that T. mcgregori most frequently overwintered on the spurs. In the present study, T. mcgregori was found principally on the spurs during the winter, and on the leaves during the spring; therefore, the principal population movement seemed to be between the leaves and the spurs. Correlation analysis between the first and second replicated samples (within trees no. 10, 23, and 83) and between the second and third samples resulted in low or negative r values in all cases (Table 4), which indicated a change in the distribution between collection dates. The high correlation coefficients between the first and third samples for trees no. 23 and 83 suggest that T. mcgregori had the same type of distribution within the tree in June as it did in early March. Perhaps this was a result of the predatory activity of T. mcgregori. When predation ceased in the fall, T. mcgregori appeared to move only from the leaves to the spurs for overwintering. Sometime after early March, T. mcgregori apparently moved from its original hibernacula on the spurs thus causing a change in its original distribution and providing the low r values between the first and second samples. This movement may have been an attempt to find suitable food in the early spring, or they may simply have been searching for active buds and leaves. As spring approached, they appeared to return to the spurs where many immature B. rubrioculus had developed. This movement returned them to their original winter and perhaps their previous fall distribution.

Typhlodromus mcgregori moved primarily between leaves and spurs during spring and summer months. Table 6 gives the results of a 24 hour study in which the number of T. mcgregori found on the leaves was compared with the number found on spurs. The 16 samples taken over a 24 hour period demonstrated that T. mcgregori spent the majority of its time on the leaves rather than on the spurs, regardless of time of day. This differed from B. rubrioculus which appeared to spend the major portion of its time on the spurs even though it did make daily trips back and forth from the leaves. Field observations in California indicated that Typhlodromus hibisci Chant and Typhlodromus limonicus (Garman and McGregor) retreated to the sheltered centers of the trees when the temperature was high during the day but returned to the periphery at night (Chant and Fleschner, 1960). Boczek (1965) suggested that phytoseiids in Poland showed a change in distribution between fall and spring,[2] and he was of the opinion that there was substantial movement to the south side of the trees during warm winter days. An attempt was made to observe winter movements of T. mcgregori on the spurs during warm days in the field and after being warmed in the laboratory, but mites were not observed moving in either case. There was no indication that either of the above movements occurred in populations of T. mcgregori since they were found principally on the leaves over the 24 hour period, regardless of temperature changes. Because of these differences in distribution

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[2] Boczek (1965) studied Typhlodromus abberans Oudemans, Typhlodromus rhenanus (Oudemans), Typhlodromus finlandicus (Oudemans), Typhlodromus pyri Scheuten, Typhlodromus soleiger (Ribaga), and Phytoseius macropilus (Banks).

and activity, the effectiveness of T. mcgregori as a controlling agent of B. rubrioculus is questionable.

The only time the distributions of T. mcgregori and B. praetiosa overlaped was in the winter when both were inactive; consequently, during this time predator-prey interaction was rather improbable. Conceivably, there could be some predation during the fall when B. praetiosa invades the spurs and again in the spring before the clover mites move out, but since the overlapping time is so short, the influence of T. mcgregori on B. praetiosa populations is probably negligible.

SUMMARY

A sampling program was initiated in an abandoned apple orchard at Highland in American Fork, Utah during the winter, spring, and summer of 1967 to determine dispersion characteristics and distributions of *Bryobia praetiosa*, *Bryobia rubrioculus*, and *Typhlodromus mcgregori*, and determine possible correlation among them. This information will aid in the evaluation of *T. mcgregori* as a control agent of *B. praetiosa* and *B. rubrioculus*.

Plots were established in selected trees and sampled periodically to determine changes in distribution in the tree. Tree trunks were banded with Tanglefoot so that the degree and direction mites moved along the trunk could be determined. Sampling spurs and leaves as well as field observations provided data concerning movement between leaves and spurs, and infesting experimental seedlings disclosed the degree and method of dispersion.

Bryobia praetiosa was the most common mite in the trees during the winter, since it used the trees for overwintering, but all clover mites left the trees in the spring. Distribution of *T. mcgregori* and *B. praetiosa* is synchronized only in the winter when they are both inactive; consequently there is probably little predator-prey interaction between them.

Bryobia rubrioculus overwintered in the egg stage in central Utah. Most of the eggs were attached to the spurs, but some seemed to be oviposited as far down the trunk as ground level. With the advent of warm

weather, the eggs hatched, and the brown mites moved to the spurs and leaves and by late spring completely replaced *B. praetiosa*. During a daily activity cycle, *B. rubrioculus* moved from the spur to the leaves in greatest numbers during early morning and late evening. *Typhlodromus mcgregori* spent the majority of its time on the leaves; therefore, that segment of the brown mite population inhabiting the spurs was essentially free from predation.

Typhlodromus mcgregori overwintered principally on the spurs, but during the summer they were most common on the leaves. Thus their primary movement occurred between leaves and spurs. There was no indication that *T. mcgregori* exploited to any degree potential prey on the spurs during warm weather, and they moved off the leaves to the spur only to hibernate. Differences in the distributions of the predator and prey species make it doubtful that *T. mcgregori* can effectively control *B. rubrioculus* or *B. praetiosa*.

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DISPERSAL OF MITES WITHIN APPLE TREES OF AN ABANDONED ORCHARD IN CENTRAL UTAH

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by
Eugene E. Nelson
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ABSTRACT

From January to July, 1967, a study of dispersion and distribution characteristics of *Typhlodromus mcgregori* Chant, *Bryobia praetiosa* Koch, and *Bryobia rubrioculus* (Scheuten) was made in an abandoned apple orchard in Highland, American Fork, Utah and in the laboratory at Provo, Utah.

Bryobia praetiosa overwintered on the spurs and other protected sites and with the advent of spring migrated out of the tree and back onto the cover crop. Coinciding with the movement of *B. praetiosa* out of the tree was the hatching of winter eggs and maturation of *B. rubrioculus* primarily on the spurs but as far down the trunk as ground level. By the middle of June, *B. rubrioculus* completely replaced *B. praetiosa* on the spurs and leaves.

The effectiveness of *T. mcgregori* as a control agent upon *B. praetiosa* and *B. rubrioculus* is limited because of the differences in their distribution during their active stages.