THE BIOLOGY OF THE BROWN ORCHARD MITE, BRYobia ARBOREA
MORGAN AND ANDERSON (ACARINA: TETRANYCHIDAE) ON
STONE FRUIT TREES IN THE DALLES, OREGON AREA

by

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To

Edward W. Anthon, who did so much to make
my college education possible
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INTRODUCTION

With the beginning of the wide spread use of DDT for insect control on agricultural crops, phytophagous mites rapidly became one of the major groups of plant pests. Since that time, and especially since the appearance of resistance of the two-spotted mite, *Tetranychus telarius* (L.), to organic phosphate insecticides, there has been a continual effort on the part of industrial and governmental research workers to develop more efficient materials for the chemical control of these pests. Knowledge of the life history and habits of these pests would add considerably to the efficiency of the control programs. The purpose of the work reported here is to help fill this need for information on the biology of one species of phytophagous mites, the brown orchard mite, *Bryobia arborea* Morgan and Anderson.

The data presented in this paper on the brown orchard mite were gathered during the past three years in The Dalles, Oregon area. The observations and experiments were carried out in orchards of the area, as well as in an insectary. The studies were directed towards obtaining information on the life history and habits of the mite in relation to the factors of its environment. In the first section the taxonomy of the brown orchard mite and the descriptions of the various instars are presented in considerable
detail. This seemed advisable because of the taxonomic confusion within the group. In the second section the methods and materials used in the studies are presented. The writer believes this to be justified because so little has been published on methods for studying the biology of phytophagous mites. A third section of this paper treats the relationship of the development of individuals to temperature. The final section presents information on the life history and habits of the mite as observed in orchards of the area.

SYSTEMATIC HISTORY OF BRYOBIA PRAETIOSA KOCH AND BRYOBIA ARBOREA MORGAN AND ANDERSON*

The data reported in this paper are the results of studies of Bryobia arborea Morgan and Anderson. Comparative morphological studies of Bryobia arborea and Bryobia praetiosa Koch are used in describing the systematic history of these two species.

Family Tetranychidae Donnadieu 1875

The name Tetranychidae was first proposed by Donnadieu in 1875 at the suprageneric level. He included many species of the Raphignathidae, Phytoptopalpidae and Tuckerellidae in the Tetranychidae. Since that time this taxon has been raised and limited until today it includes only those prostigmatid mites having the paired basal segments of the chelicera fused into a pouch-like lobe (called a stylophore) within which are anchored the curved

* The classification followed here is that of Pritchard and Baker (80, p.4).
proximal ends of the movable stylets. They also have a strong "claw" or "thumb claw" process on the fourth palpal segment. This family contains the true "spider mites".

The family Tetranychidae is divided into two subfamilies, Bryobiinae and Tetranychinae. *Bryobia arborea* and *B. preitiosa* belong to the subfamily Bryobiinae.

**Subfamily Bryobiinae Berlese 1913**

The subfamily Bryobiinae contains the most generalized members of the family. None of the species is known to produce webbing or silken threads. This subfamily is characterized by having well developed true claws, glomerate, elongate or sacculex terminations of the peritremes and duplex setae placed at the abruptly declivate distal end of the tarsus (30, p.12).

**Tribe Bryobiini Reck 1952**

The tribe Bryobiini is characterized by Pritchard and Baker (30, p.14) as having four pairs of dorsal propodosomals, the true claw developed as a curved hook or a long pad with lateral tenant hairs, and twelve pairs of dorsal hysterosomals.

**Genus Bryobia Koch 1836**

The genus Bryobia includes those mites which have the true claw uncinate and with one to several pairs of mediolateral tenant hairs.
The *Bryobia praetiosa* "Complex"

Pritchard and Baker list 19 names as synonyms for *Bryobia praetiosa*. To add even more to the confusion of the group many of the describers failed to preserve types and their descriptions and illustrations are not sufficiently clear to establish positive identifications. Later workers (19, pp.130-135) found that the life histories and habits of the mites from various areas were different, and that even within given areas populations were found on different hosts which would not inter-transfer. Mathys (19, p.141) lists four distinct races or biotypes, separated according to host plants and life history, one of which occurs only on fruit trees, one on gooseberry, another on ivy and a fourth on a number of herbaceous plants, including many legumes and grasses. Of these four, at least the fruit tree type and the legume-grass type occur in North America.

According to Pritchard and Baker (30, p.30) mites of the *Bryobia praetiosa* "complex" may be differentiated from other members of the genus by the presence of strong anterior propodosomal projections, and an empodium in the adult consisting of a single pair of tenant hairs. The dorsal setae of the body are short and broadly spatulate. Males are unreported in the literature.

The taxonomy of the *Bryobia praetiosa* "complex" has long been confused. Because the mites of this complex are entirely parthenogenetic, they cannot be separated into species on the basis of reproductive isolation. Until recently the morphological
characters had not been thoroughly examined and understood. For this reason it has long been a controversial group for the "lumpers" and the "splitters". The lumpers based their classification on the similarity of morphological characteristics, while the splitters used the wide variations in host plants and life histories as a basis for their separations.

Within the past few years Morgan and Anderson in British Columbia, following the leads of Venables (190, p.31), have made a thorough study of the biology of the "tree" form and "herb" form as they occur in that area. They found not only differences in the life histories and habits (1, pp.1-46), but also morphological differences (24, p.14) which distinguish the two types clearly. They have divided the **Bryobia pratiosa** complex, as it occurs in their area, into two separate species. The name **Bryobia arborea** Morgan and Anderson is used for the tree form. **B. pratiosa** refers to the herb form.

**Bryobia arborea** Morgan and Anderson

The name **Bryobia arborea** is at the moment a manuscript name proposed by Morgan and Anderson of British Columbia to refer to those individuals infesting trees, while **B. pratiosa** is used for those individuals infesting herbaceous plants. Permission has been given to the writer by Morgan and Anderson to use their key (24, p.14). This thesis does not constitute publication, so the name is not validated here.
Key to Eryobia praetiosa Koch and E. arborea Morgan and Anderson

"...foreleg greater than 0.69 mm. long; body length greater than 0.74 mm. long; lateral distance between bases of anterior pair of dorsocentral hysterosomal setae (DC1) greater than 0.10 mm. Larval setae lanceolate, unlike those of adult (Fig. 1A); lateral distance between bases of DC1 approximately four times length of seta...praetiosa.

"Foreleg less than 0.69 mm. long; body length less than 0.74 mm. long; lateral distance between bases of DC1 less than 0.10 mm. Larval setae foliaceous, like those of adult (Fig. 1B); lateral distance between bases of DC1 approximately twice length of seta...arborea sp.n."

The writer has compared specimens of the two species of Eryobia in The Dalles area, with the unpublished descriptions of Morgan and Anderson, and with representative specimens from British Columbia. The writer was able to separate the two forms in The Dalles area with the key and descriptions of Morgan and Anderson and to match them with the specimens furnished by N. H. Anderson (24, p.14). The writer's determinations have been verified by N. H. Anderson and several specimens have been filed in the collection of the Department of Entomology at Oregon State College.

Description of Forms

Since Koch preserved no types, and because his descriptions and illustrations are not sufficiently clear for precise identification, McGregor in 1950 (21, p.365) redescribed Eryobia praetiosa which at that time included all of the 19 species in the complex. His description is as follows:

"Female. Color reddish-brown to darker, at times with a
greenish tinge. Body from above broadly oval, somewhat flattened dorsally, noticeably truncate caudally. Striations on dorsum irregularly tortuous. Body proper above with 14 pairs of spatulate to foliaceous setae; 2 each side submarginally behind coxae II; 8 each side near margin of abdomen from humeral angle to caudal end; a transverse series of 4 setae just behind main dorsal suture; 2 pairs of submedian setae near center of abdomen. Cephalothorax anteriorly bearing a free plate between coxae I, which is distinctly 4-lobed, each lobe distally bearing a foliaceous seta. Two eye cornex on each side over and behind coxae II. Frontal tracheae terminating externally in testilike tubes. Mandibular plate obvate, somewhat notched in front. Forelegs as long as, or longer than, body; other legs shorter than body, legs II the shortest; setae of legs from linear-lanceolate to serrateclavate. All tarsi bearing 2 strong claws. Tarsus I dorsally with 2 sets of duplex setae, proximate. Seventeen or 18 setae borne proximal of proximal set of duplex setae. Onychium I with a long tenent hair borne each side near middle of each claw, a median pulvillus bearing 2 similar hairs. Tarsi II-IV each with pulvillus bearing pectinate series of tenent hairs. Last segment of palpus borne ventrally from preceding segment which bears a stout claw dorso-terminally; "thumb" subcylindrical, bearing apically a stout, lanceolate seta, and 6 additional setae on its distal half. Relative lengths of segments of legs I as follows: Trochanter, 2; femur, 29; patella, 11; tibia, 22; tarsus, 16.

"The larval stage differs from the adult female as follows; The dorsal body setae are not leaflike, but are lanceolate to clavate, and conspicuously setose; the protruding tracheae are bosslike; the free, cephalothoracic plate is lacking, but is replaced by 4 rounded protuberances, each bearing a lanceolate, pilose seta.

"Egg globular, red."

In describing *Bryobia arborea*, Morgan and Anderson use McGregor's description as a basis. Their description reads as follows (24, p.15):

"Female: In general appearance very similar to pretiosa as described by McGregor (6), but smaller in size. Body length 0.551 to 0.731 mm.; body width 0.348 to 0.527 mm.; foreleg (excluding coxa and tarsal claws) 0.513 to 0.659 mm. (50 specimens). Lateral distance between the bases of the paired dorsocentral hysterosomal setae; D01, 0.047 to 0.084 mm.; D02, 0.027 to 0.061 mm.; D03, 0.020 to 0.041 mm. (20
specimens).

"Male: Does not occur. Species entirely parthenogenetic.

"Larva: Similar to praetiosa as described by McGregor (8) but body setae foliaceous like those of adult (not lanceolate to clavate as in praetiosa). Body length 0.172 to 0.193 mm.; body width 0.113 to 0.164 mm. (20 specimens). Lateral distance between the bases of the paired dorsocentral hysterosomal setae: DC₁, 0.035 to 0.053 mm.; DC₂, 0.017 to 0.030 mm.; DC₃, 0.013 to 0.022 mm. (25 specimens).

"Egg: Spherical, slightly flattened at base. Size: 0.136 to 0.178 mm. diameter (50 specimens)."

In examining specimens of B. arborea collected in The Dalles area, the writer has observed the following additional differences from the descriptions of McGregor and of Morgan and Anderson. The peritremes (called "frontal trachea" by McGregor) appear to have a perforated teat-like knob which is partially hollow, (Figure VIII); color of the adults vary from an orange-brown or tan in specimens which had not fed after moulting, to a dark olive green in fully fed specimens. Newly hatched larvae are scarlet-red in color, changing to a dark olive green after feeding; their peritremes have a bifurcate knob, the outer fork being longer and curved inward (Figure VIII).

The writer has not found any descriptions of the two nymphal instars of B. praetiosa and B. arborea in the literature. Since the various instars must be identified in the course of biological studies, the writer is describing these stages as follows:

Deutonymph: Similar to the adult female in general body shape and color, but differing in size, relative length of the
forelegs, and shape of the peritremes.
Body length 0.48 to 0.59 mm.; body width 0.39 to 0.50 mm.; ratio of body length to leg I, 1.49 to 1.53:1.
The peritremes end externally in a loop with an extra knob on the mesal edge of its base (Figure VIII).

Protonymph: Similar to the deutonymph, but differing in size, relative length of foreleg and shape of peritremes.
Body length 0.37 to 0.45 mm.; body width 0.31 to 0.38 mm.; ratio of body length to leg I, 1.73 to 1.8:1.
The peritremes end externally in a loop with a knob on the dorsal side of its base (Figure VIII).

Common Names

Anderson and Morgan (1, p.2) list 16 common names from the literature for the Bryobia praetiosa complex. Of these, the clover mite, the brown orchard mite and the brown almond mite are probably the most widely used in western North America. In much of the literature, the name clover mite has been used for both the tree and herb forms. Throughout this paper the tree form, Bryobia arborea Morgan and Anderson, will be referred to as the brown orchard mite.

Distribution

Bryobia arborea Morgan and Anderson appears to be cosmopolitan in distribution, but since this species has only recently been
recognized, it is included in _B. praetiosa_ in all the literature. The tree form of _B. praetiosa_ has been reported from North and South America, Europe and Australia (9, p.140; 10, p.456; 19, p.138 and 40, p.41). Also it probably occurs in Africa and Asia as there are numerous reports of _B. praetiosa_ from these areas, some including forms living on deciduous trees.

**METHODS AND MATERIALS**

**Collecting**

Specimens of _Bryobia arborea_ used in life history studies in the insectary were collected from peach and cherry trees by bringing portions of the infested plants into the laboratory and removing specimens from them. The living mites were moved from place to place by means of a small, number one, dry camel hair brush. Specimens of _B. praetiosa_ used for morphological studies were collected from herbaceous plants in the same manner or were collected from Berlese funnel samples of trash gathered from around tree trunks and buildings.

**Mounting and Staining**

Specimens of both _B. arborea_ and _B. praetiosa_ were mounted on slides for comparative study and for the preparation of drawings. Mites were removed from the host with a small teasing needle and placed directly into a drop of mounting medium on a glass slide. The teasing needle was made by sticking a minuten insect pin into
the end of a small glass rod softened in a gas flame.

The specimens were mounted alive. This method proved better than collecting in alcohol and mounting later, as it required less handling of the specimens and produced better mounts. Alcohol tended to harden the specimens and rendered them difficult to clear. The best results were obtained when only one specimen was placed on a slide.

The best mounting medium for the brown orchard mite proved to be Hoyer's, a modified Berlese solution, described by Pritchard and Baker (30, p.2). Staining was especially necessary for larval specimens, because they often cleared so completely as to be almost invisible under the microscope. This was done by adding a few crystals of picric acid to the stock bottle of Hoyer's medium. The crystals gave the medium a very transparent yellow cast. Although almost unnoticeable in the medium, the exoskeleton of the mites was stained considerably, and the color did not fade with time.

The fresh slides were placed in an oven at 55º C to clear the specimens. The time required for clearing the mites varied with their stage of development and the amount of brown pigment in their bodies. Newly hatched nymphs were cleared in 24 to 48 hours, while it was necessary to leave adult specimens in the oven for a week or 10 days. Thus the slides had to be checked from time to time and removed from the oven when the specimens were properly cleared. Some clearing occurred after the slides were removed...
Mites were reared in individual cages so as to make possible daily observations on their developmental progress. Individual specimens were reared in the insectary by placing them in small cages firmly clamped to the surface of the leaf of the host plant. Spring-type wooden clothespins were the bases for these cages, which were constructed as follows: A 3/16 inch hole was drilled in one jaw of a clothespin about 3/8 inch from the end. The inner surfaces of both jaws were then ground with an emery wheel until they were smooth and fit together evenly when the clothespin was closed. The jaw with the hole bored in it was ground with an emery wheel on the outer surface until it was smooth and parallel with the inner surface. The jaw remaining was about 1/8 inch thick. A piece of ethyl acetate 1/2 inch square was glued with balsam to the outer surface of the jaw so that it made a window over the hole. A piece of felt weather stripping was glued to the inner surface of the other jaw, and the glue was allowed to dry. After some practice these cages could be quickly and precisely constructed. Each cage was identified by a number written on it with pencil.

The cages could be used over many times. After each use the plastic window was removed and the cell cleaned by sanding it with fine sandpaper rolled into a rod. This removed any eggs, debris
or dead mites which might confuse observations during the next use.

The requirements of a good cage are: to confine individual mites in as nearly normal conditions as possible; to allow quick and easy manipulation of the mite in and out of the cage. The cage described above met these requirements better than any of the others tried. The brown orchard mite, as a transient feeder, moves back on to the wood or bark of the plant after feeding to moult and to deposit its eggs. The clothespin cages provided the wooden surface for these activities. The felt on the lower jaw of the cage served as a cushion for the leaf and held it firmly against the upper jaw, to prevent the escape of the mite.

The cages were too heavy to hang on the leaves of cherry and peach seedlings. To prevent the cage from damaging the host plant, a heavy wire was stuck into the soil at the base of the plant and bent at a right angle about one inch from the top end at the height of the cage. The bent end of the support was slipped through the spring of the cage so that most of the weight of the cage was supported by the wire.

The host plants used for rearing *Bryobia arborea* were Mazzard cherry seedlings and Lovell peach seedlings. The cherry seedlings were obtained from Dr. J. A. Milbrath, Department of Botany, Oregon State College. The peach seedlings were grown from seed at the rearing site. The two-spotted spider mite, *Tetranychus telarius*
(L.), was a constant pest of these plants as no control measures could be practiced while the caged mites were on them. Except for damage to the foliage by the two-spotted spider mites, the host plants were not noticeably affected by their mite infestation and grew satisfactorily. It is not known whether the feeding injury to the host plants by the two-spotted mite affected the development of the brown orchard mites.

Observations with a stereoscopic microscope were made of the individual mite in each cage. The position of the mite in the cage, its activity, and its developmental progress were recorded daily. The records were kept on data sheets provided with a small circle for each observation so that the mite's position could easily be checked in relation to that of the previous day. This was necessary in order to tell whether the specimen was in an active or quiescent state.

The best method of lighting the cages during observations was to fasten a light to the microscope so that it was directed on the focal point of the objective.

Throughout most of the rearing work, observations were made by holding the microscope in one hand and bringing the cages into focus with the other. For this procedure, the base of the microscope was removed at the sliding dove-tail joint. The frame remaining was used as a handle. While making the observations it was necessary to sit with both arms rested on the table so that the microscope and the cage could be held steadily.
Near the end of the rearing project another method of making the observations was tried which was far superior to that described above. A support with two shelves was built; one was the same height as the plant pots and a second was 1\(\frac{3}{4}\) inches lower and extended two inches beyond the front edge of the first. The upper shelf was made of one by four board, the lower shelf and the ends of one by six boards. This support was three feet long. A seedling cherry tree in a plant pot was bent over each end of the support and fastened flat to the top shelf. The rearing cages were placed on the leaves so that they too rested on the top shelf. The base of the microscope was then pushed between the shelves until the cages were within focusing range. The microscope could be easily moved along the lower shelf until it was in line with the proper cage. Ten or 12 cages could be set upon such a unit and the observations could be made quickly and accurately.

**Rearing-site**

The rearing was done in a nylon-screen enclosed insectary. This afforded partial shade and shelter from the wind and rain, yet did not alter the environment as much as a greenhouse. Temperatures in the shelter were usually 2 to 4 degrees higher than the outside air temperature at the experiment station.

**Collecting and Processing Temperature Data**

A Fries hygro-thermograph was used to record the temperature
and humidity at the rearing site. The instrument was kept inside the insectary close to the rearing area. It was placed in a ventilated wooden box to shield it from the direct sun. Tables of the maximum and minimum daily temperatures and relative humidities were made from the hygro-thermograph charts. The mean temperature and relative humidity for each day were derived as the average of the maximum and the minimum. The mean temperatures for each of the days during the developmental period of each specimen were averaged, and this value was used as the average mean developmental temperature for the period.

The data were condensed by grouping together individual rearing tests with similar results. Only data from the same season of the year were grouped together.

Orchard Observations

The biology of *Bryobia arborea* in the orchards of the area was studied by direct observations on natural populations. Egg counts, population counts, and checks on the seasonal development were made by bringing twigs from infested orchards into the laboratory where observations were made with a binocular microscope. Samples were taken at seven to 10 day intervals. Between 2,000 and 3,000 mites were counted from each sample. Counts were made on both leaves and twigs. Observations on feeding and migration habits were made in the orchard without disturbing the mites. At the time the observations of the mites were made temperature and humidity readings were
made with a sling psychrometer. These readings were correlated with local observations on feeding and migrations.

Summers and Baker (37, pp.369-382) reported on a procedure for counting brown orchard mites on almond trees which involved beating twigs over a heavy screen or wire mesh to knock the mites onto a paper. This method was tried at The Dalles, but many of the mites in the quiescent stage were not knocked loose by very severe beating of the twigs against the mesh. For this reason the method is not applicable to biological studies, especially where relative numbers of various instars are needed.

THE RELATIONSHIP OF TEMPERATURE TO DEVELOPMENT OF THE BROWN ORCHARD MITE

One method of studying the effects of various environmental factors on the rate of development of organisms is to correlate observed rates of development of individual specimens with factors of the environment as measured at the site of rearing. The results from individual rearing are more accurate than those obtained from observations of colonies or mass rearing studies. They also lend themselves more readily to statistical analysis, so that a more thorough evaluation of the data can be made.

In this section temperature-development time relationships obtained from individual rearing tests of the brown orchard mite are discussed. Records of relative humidity were also made, but the range of mean humidity at the rearing site proved not to be significant. The diurnal fluctuations in relative humidity were
as high as 75%, but the mean relative humidity values outside the rearing cages for periods of a week or longer were nearly the same during the two seasons the tests were conducted. Mean relative humidities in the insectary for periods of 10 days fell within a range of 60 to 70% from April to October.

The Egg Stage

Because most of the adults kept in individual cages laid mostly winter eggs, not much data are available for the summer egg stage. The incubation period for summer eggs varied between eight and 17 days and averaged about one and one half times longer than the larval stage at a given temperature. The incubation periods of 47 eggs were observed during the individual rearing studies.

A total of 4375 winter eggs on 10 six-inch lengths of cherry twigs were collected in October and held for 105 days at 41° F. to break their diapause. After receiving the cold treatment, the eggs were incubated at 70° F. The number of larvae hatching from the eggs was counted each day. All the viable eggs hatched within 15 days incubation. More than 50% of the eggs hatched within seven days.

Termination of Diapause in the Overwintering Egg

In the case of some insects and mites, diapause is terminated only after exposures to temperatures within a certain range for a minimum period of time. Lees (15, p.4) states that in organisms
with this type of diapause, there is a "diapause development", which occurs only when temperatures are within a critical range.

Tests were conducted to determine the requirements for termination of diapause of the overwintering eggs of the brown orchard mite. Ninety twigs six inches in length containing overwintering eggs were collected on October 10. Twenty of these twig samples were kept in a room at 70° F. to incubate the eggs. Separate groups of 10 twigs each were exposed to 22° F. for periods of 48 hours, 30, 57, and 117 days. Similar groups of twigs were exposed to 41° F. for 58, 105, and 150 days. After the cold exposure periods the twigs were kept at temperatures near 70° F. to incubate the eggs. The number of larvae hatching from the eggs was counted each day for each group until no more hatching occurred (Table VI).

A simple "cold shock" is probably not the factor responsible for the termination of diapause of the overwintering eggs of the brown orchard mite since there was a low percentage hatch of eggs exposed to freezing temperatures for 48 hours and 30 days. Temperatures of 41° F. are more effective than temperatures of 22° F. in terminating diapause, regardless of the exposure time. Diapause was terminated in only about 8% of the eggs exposed to 22° F. for 118 days, while 100% of the viable eggs hatched after 105 days exposure to 41° F.

The writer did not determine whether the eggs exposed to 22° F. would hatch after exposure at 41° F. for a sufficient time to break diapause, so a definite statement on the lethal effects of freezing
temperature cannot be made. However, probably the freezing temperatures did not cause significant mortality of the eggs. Eggs which failed to hatch after exposure to 22° F. remained round and turgid during several weeks' exposure to 70° F. The eggs receiving no cold treatment also remained turgid for more than 150 days at 70° F. Temperatures of 22° F. or lower commonly occur in the Dalles area during the winter. Nearly all the eggs which remain turgid and red throughout the winter hatch the following spring.

Lees (14, p.475) reported that temperatures between 34° and 48° F. were nearly equally effective in terminating diapause of the overwintering eggs of *Metatetranychus ulmi* (Koch), the European red mite. He also found that "freezing" the eggs at 23° F. failed to break diapause, regardless of the length of the exposure period. He also states that low temperatures within the range normally occurring during the winter months seem to be the only important environmental factor involved in the termination of diapause in the European red mite.

The Immature Stages

The results obtained in individual rearing tests for the temperature-development time relationships of the post-hatch stages of *Bryobia arborea* are presented in the appendix. Tables I, II, III and IV list the data obtained for the temperature-development time relationships. The lines of least squares, the regression coefficients and the correlation coefficients are included. The
line of least squares is drawn in the graph of the temperature-development relationships for the period from eclosion to the adult (Figure IV). The line of least squares is not drawn in the graphs of the temperature-development data for the individual instars because there is insufficient data to accurately determine straight line relationships.

Discussion of Results

There is a general tendency for the development-rate temperature data to group around a median range of temperatures. This occurs because the daily temperatures normally encountered during the season that the organism is active, form a normal distribution around a certain mean temperature. Lower or higher temperatures occur less frequently at increasingly greater deviations from this mean value. Also of importance in the distribution of the data collected under natural conditions is that more individuals tend to develop within the median range of conditions.

In the course of the studies reported here, an average of 25 rearing tests were maintained throughout the season when active stages of the brown orchard mites occurred in the orchards of the area. No attempt was made to modify the temperature or to conduct larger numbers of tests under extreme temperature conditions. For this reason there are much more data within the intermediate ranges of temperature than at either extreme.

It has been shown by Sanderson and Peairs (34, p.12) and by
Krogh (13, pp.163-177) that throughout the median range, a temperature increase of one degree always produces the same acceleration in rate of development. Within limits, the development time-temperature curve is a hyperbola, and its reciprocal is a straight line. The rate of acceleration slows down at the upper and lower limits of the developmental range. Thus, there are three separate rates of acceleration by temperature throughout the range of development; one slower rate just above the threshold of development, a faster rate throughout the median range, and another slower rate at temperatures above this median range.

At temperatures below 65° F. the data for temperature-development time of the period from eclosion to adult for the brown orchard mite fit a straight line reciprocal relationship rather closely (Figure IV). Within a temperature range of 55° to 65° F. (and perhaps even lower) temperature seems to be the chief factor in determining rate of development.

The work of Sanderson and Peairs and of Krogh, was done in the laboratory under constant temperature conditions and controlled environments. Within the natural environment of an organism, one would expect other factors of the environment, in addition to temperature, to influence the rate of development. This seems to be illustrated by part of the temperature-development time data reported here for the brown orchard mite.

The rate of acceleration of development seems to change at temperatures above 65° F. The slope of a line fitted to the
reciprocal data above this temperature is flatter than a line fitted to the data at lower temperatures (Figure IV). This indicates that at mean temperatures above 65° F., temperatures could be occurring during the warmer parts of the day which are beyond the median range of development.

The data obtained at temperatures above 65° F. are scattered and do not fit a straight line very closely (Figure IV). This scattering of the data may be the result of factors other than temperature affecting development. At 67° F. the observed development time was 16 days, at 71° F. it was 12 days and at 72.5° F. it was 15 days (Table IV). These fluctuations above and below a median line could indicate that at certain times certain favorable factors were effective, while at other times unfavorable factors were effective. The writer has no experimental evidence to indicate what these additional factors were. However, the nutritional quality of the host plants and the physical effects of maturation of the leaves may be factors of considerable importance in the rate of development of this mite.

In addition to the above factors the homogeneity and variation of the data could be affected by the length of the period between observations. At temperatures between 65° and 70° F. the development periods of the various instars ranged between three and five days. Since the observations of these individually reared mites were made at daily intervals, there was a possible observational error of almost one day, which is 1/3 to 1/5 of the development period. When development
periods were longer, the possible error was proportionally less. If the rate of development of the brown orchard mite is slowed by temperatures associated with daily mean temperatures above 65°F, one can make an interesting correlation between this and the seasonal trends in populations occurring in cherry and peach orchards. As mentioned in the section on life history and habits, unseasonally warm weather during June, 1955 was associated with a decrease in the total active population of mites in orchards in The Dalles area. A slowing down of development rate at higher temperatures may be one of the reasons why the largest populations of this mite occur during the spring and fall. This condition is just the opposite of that occurring with *Tetranychus mcdanieli* McGregor, the other important spider mite pest of stone fruit trees in the area, which builds up to peak populations during July and August.

The three immature stages of the brown orchard mite showed similar developmental responses to temperature. No one stage was more responsive or less responsive than the others. The data also show the lengths of the various stages to be almost the same at the same mean developmental temperatures. The length of the larval stage varied from 28.3 days at a mean development temperature of 49.5°F to three days at 76.2°F. The 28.3 day development period was observed during April and early May of 1955. During that period temperatures in The Dalles area were considerably below normal.
Length of Generations in the Insectary

Under conditions of individual rearing tests in the insectary, the length of a generation of the brown orchard mite ranged from 21 to 63 days. The length of a generation was calculated by including incubation periods ranging from eight to 17 days, combined developmental periods of the three immature instars ranging from 11 to 41 days and preoviposition periods ranging from two to five days. At mean temperatures between 60° F. and 70° F., which normally occur during May, June and July in The Dalles area, the length of generations range from 28 to 40 days in the insectary.

LIFE HISTORY AND HABITS

This section presents the life history and habits of the brown orchard mite in fruit orchards of The Dalles area. Life history studies of other workers are compared and discussed in relation to the findings of the writer.

The life cycle of the brown orchard mite includes an egg, a hexapod larva, a protonymph, a deutonymph, and an adult. Each immature stage includes a quiescent period which is terminated by moulting. The life cycle differs from that of most other Tetranychid mites in that this species is entirely parthenogenetic; males have never been reported. Anderson and Morgan (1, p.4) prefer to consider the quiescent periods as separate stages. They report that the mites pass through four active and three resting stages as follows: larva, protochrysalis, protonymph, deutochrysalis, deutonymph,
telochrysalis, and adult.

Overwintering

Reports in the literature (1, p.17; 7, p.140; 8, p.188; 10, p.456; 35, p.96 and 36, p.643) and observations by the writer indicate that the brown orchard mite, *Bryobia arborea* Morgan and Anderson, overwinters in the egg stage, at least within the temperate areas of its distribution. The overwintering eggs are deposited in the crevices of the bark of twigs, small branches, and fruit spurs. They are commonly laid in and among the exuviae of the developing summer generations and when the populations are large, the accumulation of cast skins, the deposited eggs, and the dust and debris collecting in these rough areas often give the infested limbs a gray or whitish cast on the underside and in areas with rough bark. During the fall and winter the cast skins and debris are weathered away leaving the eggs exposed. By spring they appear as bright red masses and when many of these masses are present they give the underside and sheltered areas of the bark a bright reddish cast.

On the other hand the clover mite, *Bryobia praetiosa* Koch, overwinters in all the active stages as well as the egg stage. These mites are often found in the vegetation and debris around orchard trees and many overwinter in the rough bark of the trunks and large scaffolding branches. These should not be confused with the brown orchard mite which has been found only on the twigs as
mentioned above.

Development of the First Generation

The development of the first generation of the brown orchard mite differs in a number of ways from the development of the summer generations. Part of these differences result from the mites' hatching from the overwintering eggs and from the effects of cold temperature on their development. These and other differences are discussed below.

Hatching of the overwintering egg

In 1955 the first overwintering eggs began hatching on April 6 and in 1956 hatching began on April 2. This hatching of winter eggs continues until about May 1, with the peak occurring about one week after the first hatch (Figure V). Hatching then drops off rapidly and only a few viable eggs remain after ten days. In 1955 and 1956 the eggs began to hatch when the green tips were just beginning to show on cherry and peach trees. The peak of hatch occurred when cherry blossoms were in the balloon stage and peach blossoms were beginning to open. Anderson and Morgan (1, p.11) state that in British Columbia winter eggs begin to hatch while McIntosh and Delicious apples are in the late delayed dormant to early "mouse ear" stage of development. Other reports from Europe, Australia and the United States (10, p.456; 19, p.141 and 38, p.8) indicate that the time of hatch of the overwintering eggs of the brown mite is
correlated with the beginning of growth of the host plants.

**Larvae**

The larvae hatching from the overwintering eggs begin to feed on the tips of the opening buds when temperatures are warm enough for their activity. Within a short time they change color from scarlet or reddish orange to a dull greenish brown similar to the color of the bark on the twigs of peach and cherry trees. They also become plump and their abdomens are somewhat extended. However, if the weather is cold during the egg hatching period the larvae may not feed for some time. They retain the scarlet color until after they have fed. This situation occurred during the egg hatching period in 1955, when average daily temperatures varied from 44°F to 55°F between April 1 and April 21. The newly hatched larvae gather in large masses in rough places on the bark, in the axils of the lateral buds and between the opening bud clusters. When twigs containing these masses of newly hatched larvae were placed indoors, at temperatures of 65°F to 70°F, the larvae became active in two to four hours and wandered rapidly over the stems and partially opened buds. These masses of mites on the twigs were found for 14 days after hatching began.

As the larvae begin to feed, many are trapped on the sticky surfaces of the unfolding leaves or become entangled in the leaf hairs. The condition is especially prevalent on cherry trees. On some twigs as many as 15 to 20% of the larvae present are ensnared
in this manner. Examination of twigs during the early hatching period indicated that 10% or more of the first generation larvae are killed in this way.

After feeding, the larvae return to the rough areas on the bark where their dull green color blends in with their surroundings. They remain in these areas with little activity until they are about to enter the quiescent period. They then seek a sheltered place and settle down tightly, often being partially or completely hidden in a crack or crevice. The front legs are doubled under at the genual-tibial and tibial-tarsal joints and the claws are fastened securely to the bark. The claws of the remaining legs are also attached to the bark, but the folding under is not pronounced. The mite remains in this position until it molts into the next instar. The quiescent period lasts for four or five days during the spring, but is as short as one to two days during the summer.

**Ecdysis**

The first apparent step in ecdysis is the lateral splitting of the old cuticle on the dorsal side between the propodosoma and the metopodosoma. The opening is widened by body movements and the dorsal surface of the new instar is forced out as the two halves of the old cuticle begin to loosen and slip away from the ends of the body. The legs seem to be the last part to come loose. The old cuticle may split entirely in half during the molting process and when this occurs the posterior portion often breaks loose from the host plant.
and the new instar fails to escape from this portion for some time. Mites with this posterior portion of the old cuticle unshed were commonly seen during the periods of the first and second moulting of the first spring generation. When this situation occurred with mites being individually reared, the old cuticle was lost in a short time and did not seem to impair the activities of the mite. In normal ecdysis, however, the old cuticle remains attached along the ventral side and the new instar emerges cleanly, leaving it attached to the host plant by the legs. These cast skins remain on the host plant for long periods of time and in areas of heavy infestations, they persist well into the winter.

In 1955 the first moulting of the larvae was observed on May 2 and the peak of larval moulting occurred about May 6. In 1956 the first larval moulting was observed April 10 and the peak of larval moulting occurred about April 15 or 16.

Protonymph

The instar emerging at the first moul is the protonymph. Upon completion of moulting the nymphs are again active and, if climatic conditions are suitable, they move from the twigs onto the foliage and begin feeding. Before feeding the nymphs are pale orange to tan with small olive green spots within their bodies giving them a mottled appearance. Two distinct red spots, the eyes, stand out prominently on the lateral frontal corners of the dorsal surface of the propodosoma. During feeding, their bodies again
take on a greenish-brown color, while the appendages remain tan. After feeding these protonymphs return to the twigs to seek a sheltered place in which to pass the quiescent period. The active protonymphal stage lasts only a few days unless temperatures are so low as to impede development. Within one or two days after feeding, the protonymphs enter a quiescent state which is terminated by moulting and the appearance of the deutonymph. The quiescent stage is normally one or two days in length, but if temperatures are low, it may last as long as five days. Moulting occurs in the same manner as described for the larval moul.

**Deutonymph**

The second nymphal instar or deutonymph differs from the protonymph mainly in size. The feeding and resting habits are the same in every respect observed. The newly emerged deutonymphs are again a light tan color and actively move about seeking a feeding site on the foliage. As they feed, they take on an olive-green color and the abdomen is expanded until they appear plump and rounded. After feeding they return to the twigs to hide until they enter the quiescent period. Within one or two days the quiescent period is terminated by moulting and the emerging of the adult.

**Effect of temperature on development of the immature instars**

The time required for the complete development of the first spring generation of the brown orchard mite depends to a large extent
on the temperature and the development of the host plant. Some of these relationships are considered in the previous section. The effects of temperature are by far the greatest and are of both a primary and secondary nature. First, the temperature affects the rate of development of the individual mites, both in the active and quiescent periods. The rate of feeding is also effected by temperature. When temperatures are below 40° or 45° F. as they were in the spring of 1955, the mites do not feed. After hatching, the larvae gather in masses at the bases of buds or other sheltered places during the cold periods. Temperature also affects the rate of development of mites of the first generation secondarily by its effect on the host. In some areas during the 1955 season, many of the eggs hatched before the buds had developed enough to allow the larvae to feed. The weather remained cold for more than a week and buds developed very slowly, providing a very limited feeding area for the mites.

Adult

In 1955 the peak in the adult population of the first generation of the brown orchard mite occurred about May 24, while the corresponding peak during the 1956 season occurred about May 8 (Figure V). In 1956 this peak developed about the time of pit hardening of cherry fruits in the area. Anderson and Morgan (1, p.13) report that the peak in the adult population in British Columbia apple orchards occurred during the third week of May in 1954; but not until the beginning of June of the 1955 season.
Within two to five days after moulting the adults begin to deposit eggs on the twigs. The first eggs were deposited on May 21 during the 1955 season, while during the 1956 season the first eggs were deposited during the first week of May. The mites go through a succession of alternate feeding and egg laying activities throughout the remainder of their life. In individual rearing experiments in the insectory it was found that the adult mites laid from one to four eggs per day or at one time. Often one or two days elapsed before additional eggs were laid. During this period the mites were observed hiding in rough places in the cage or feeding. The adults lived from one to three weeks in individual cages during the late spring. The maximum number of eggs deposited by a single mite was 31 and the average number of eggs deposited was 9.6. Anderson and Morgan (1, p.13) stated that upon moulting the adults feed for one or two days before beginning to deposit summer eggs. They stated that each mite probably lays about 30 eggs. The author's figure of 9.6 may not be comparable with the estimate of Anderson and Morgan as it represents observations under unnatural conditions of confinement. No attempt was made to determine the egg laying capacities of mites in their natural habitat.

Summer Generations

The peak of egg hatch of the second generation in the orchards of The Dalles area, as measured by the number of newly hatched larvae present on twigs and leaves occurred about June 10 during the 1955
season and about May 30 during the 1956 season. Anderson and Morgan (1, p.14) stated that the second generation begins in the latter half of May or first part of June in British Columbia orchards.

Due to the extended oviposition period of the first generation adults, the various stages of the summer generations overlap each other. This overlapping becomes more pronounced as the season progresses, and many individuals of the second and third or third, fourth and fifth generations may be present on the same twig or branch at the same time. During the 1955 season this overlapping was so complete that no peaks in the population of the various stages of the different generations were evident. Also, during the month of June of that year 10 days of unseasonably warm weather occurred. This warm weather was associated with a great decrease in the total population of mites and an increase in the percentage of winter eggs deposited.

During the 1956 season, however, weather conditions were moderate throughout the summer, and the mite population remained much higher in the orchards of the area. Population counts made at 7-to 10-day intervals throughout that season seemed to show a progression of the generations throughout the season (as indicated by the percentages of the various stages at different times), (Figure V). The data indicates four distinct peaks and a smaller fifth peak of adults in the population during their active season. In British Columbia (1, p.17) there are reportedly four generations per year. Miller (23, p.111) reported that there are at least four generations
in Ohio and in some cases as many as eight. Other authors report three, four, or five generations per year on orchard trees (40, p.41 and 16, p.302).

Summer-Winter Egg Deposition

There are two types of eggs laid by the brown orchard mite: the summer egg which hatches the same season it is deposited, and the winter egg which does not hatch until the spring following its deposition. In The Dalles area most of the eggs deposited by mites of the first generation are summer eggs and hatch within two weeks, although some are of the winter type. As the season progresses the proportion of winter eggs increases. The percentage of winter eggs deposited by the mites during any one season of the year is influenced by weather conditions and probably by quality and availability of the food supply. Dry, hot weather during June of 1955 greatly reduced the populations of active brown orchard mites in fruit orchards of the area and most of the eggs deposited by the remaining individuals were of the winter type. During the 1956 season, the build-up of winter eggs occurred more slowly than during the preceding year. Most of the winter eggs were deposited during August and September of this season (Figure V). Even during September of the 1956 season a few summer eggs were deposited and an occasional immature form was found. Thus, at least during certain years, the mites lay some summer eggs throughout the season.

Other workers (1, p.19 and 37, p.370) report the build-up of
winter eggs earlier in the season. In British Columbia as many as 98% of the eggs present on the twigs during the first week in July fail to hatch until the following season. This may be due to the summer eggs being deposited on the leaves in that area. It may also be the result of the summer eggs of the first generation having hatched, leaving only the winter eggs on the twigs. The immature instars of the second generation develop during the last part of June and first part of July. Most of the adults of the first generation die before this time, so there are few new eggs being deposited.

Feeding and Migrating

The feeding habits of the brown orchard mite differ widely from the habits of other phytophagous mites on fruit trees. The immature instars feed once or rarely twice between moults. This feeding period lasts from a few hours to a whole day and is followed by a period of quiet hiding on the bark before the quiescent period begins. Both the immature forms and the adults return to the bark during adverse weather. The adults were observed to feed intermittently throughout their egg laying period. One old concept was that these mites fed only during the night, or mainly at night (27, p.12). The opposite of this was found to be true in The Dalles area. Here most of the feeding occurs during the day. Some of the mites of the summer generations remain on the leaves at night and probably feed during this time. During mid-summer, mites were observed actively feeding at temperatures as low as 60° F. and as high as 91° F. Mites feeding
at temperatures above about \(80^\circ\) F. remained in the shade and when the leaves on which they were feeding were placed in the sun they soon began moving about randomly and often went to the lower side of the leaf. Summers and Baker (37, p.370) reported that the feeding population on almonds in California stabilizes during daylight hours when temperatures are within approximate limits of \(70^\circ\) to \(85^\circ\) F.

The transient feeding habit of the brown orchard mite is most pronounced during the first generation and as the season progresses more time is spent on the leaves. During the mid-summer, much of the egg deposition and moulting occurs in the upper groove of the midrib. On trees heavily infested the upper groove of both the petiole and the blade midribs are unevenly filled with eggs, cast skins and quiescent immature mites. Whether or not the eggs on the leaves were only of the summer type or whether there were both summer and winter eggs present was not determined. Anderson and Morgan (1, p.17) however, indicate that the summer eggs are laid on the leaves while the winter eggs are deposited on the bark of the twigs and that migration during the summer consists only of the adults going on to the twigs to deposit winter eggs. Summers and Baker (37, p.369) state that the brown orchard mite in California spends most of its life on the bark, migrating to the leaves only for the purpose of feeding.

The writer found no evidence to indicate that the brown orchard mite migrates from tree to tree. No brown orchard mites were found in samples of alfalfa in the orchards or in samples of bark on and
about the bases of trees infested with them. Anderson and Morgan (1, p.17) banded tree trunks and scaffold limbs with tangle foot and found no evidence of migration to these parts of the host trees.

Although the brown orchard mite migrates frequently from wood to leaves, the dispersal from infested to uninfested areas of a tree is very slow. Migration to the larger scaffolding branches does not seem to occur. Infestations are often limited to the central portion of a tree or to one section of a tree. Local populations build up to large numbers and feeding injury is quite severe before infestations begin to appear in adjacent parts of the tree. Summers and Baker (37, p.370) point out that the spatial distribution of mites on host trees is correlated with the surface pattern of bark, especially on young trees. The degree of roughness and other characteristics of the bark in some way determine where the mite populations will reside during the quiescent and ovoposition periods. They also mentioned that young, vigorously growing peach and almond trees are seldom seriously damaged by brown orchard mites, although they often support small populations of the pest.

Seasonal Abundance and Damage to the Host Plants

Populations of the brown orchard mite vary greatly from season to season and from orchard to orchard. The highest population throughout the season often occurs during the first or second generations. During hot, dry summers, as occurred in 1955, the summer populations are low and the spring and fall populations dominate in
the orchards. During moderate summers, as occurred in 1956, the summer populations of this mite may remain high.

The most severe damage to fruit trees occurs during the early spring when the foliage is not fully developed. The overwintering eggs hatch well before those of the European red mite, *Metatranynchus ulmi* (Koch) and the first generation develops before and during blossom and fruit setting periods. One author reports that the brown orchard mite causes blossom damage and reduces fruit set (10, p.456). When populations are high, the mites cause considerable stippling of the leaves. At no time during the 1954, 1955 or 1956 seasons did the infested leaves turn brown or drop, which so often is the result of the feeding of heavy populations of other phytophagous mites in the area.

Host Plants

In The Dalles area, brown orchard mites were observed on all varieties of sweet and sour cherries, *Prunus avium* and *P. cerasus*; peach, *Prunus persica*; plum, *Prunus domestica*; western choke cherry, *Prunus demissa*; apple, *Pyrus malus*; and pear, *Pyrus communis*. These mites were not found on apricot, *Prunus armeniaca* even though these trees were growing in mixed plantings with peach or cherry. This mite has also been reported from almond, *elm*, poplar and some coniferous trees (37, p.370 and 1, p.20).

In The Dalles area the mite did not seem to show preference for either peach or cherry or for any of the many varieties of either
host. Apple and pear trees are grown only on a small scale in this area and their relative importance as hosts for this mite was not evaluated. However, in the Okanagan Valley of British Columbia, apple is reported to be the preferred host, with Delicious and Newtown being preferred varieties over Jonathan and Winesap (1, p.19). Summers (38, p.6) reported the brown orchard mite as an economic pest of apricots as well as peaches and almond.

Since the mite is completely parthenogenetic, it might well be that the various populations readily adapt to the hosts present in a given area without the interference of gene flow from neighboring populations. However, this does not explain why this mite feeds on apricot in California, but not in The Dalles area.

Natural Control

Bryobia arborea, unlike other phytophagous mites, does not seem to be controlled by the natural complement of predators in unsprayed or abandoned orchards. In fact it is usually the most prominent of all species under these conditions. In The Dalles area, the only predators known to feed on brown orchard mite and commonly found associated with them are Mediolate mali Ewing, Typhlodromus rhenanus (Oudemans), two species of predaceous mites, and Anthocoris spp. However, certain coccinellids probably also prey on this mite.

Mediolate mali overwinters as an adult or nymph and is commonly found associated with the winter eggs of B. arborea. It becomes active in the spring as the host plants begin to break dormancy and
begins feeding on the overwintering eggs. It is also present among populations of brown orchard mites throughout the summer. The other three predators mentioned are active during the growing season and feed on the active stages.

The relative effectiveness of these predators was not determined in the course of these studies. However, there is evidence that predators have a moderating effect on populations of B. arborea. At the experiment station in The Dalles, several of the plots were sprayed with chlorinated hydrocarbon insecticides. Rapid increases in the populations of the brown orchard mite occurred in the treated plots. These high populations persisted into the year following the insecticide treatments. Chlorinated hydrocarbons are known to be highly toxic to many of the common predators of phytophagous mites.

Anderson and Morgan (1, p.11) reported that abandoned orchards in the Okanagan Valley of British Columbia usually support large populations of this mite. They further state that, although several species of predators feed readily on the brown orchard mite, they play only a minor role in controlling it. They list 21 species of mites and insects as having been reported preying on brown orchard mites.

**SUMMARY**

The purpose of the work reported here is to help fill the need for information on the biology of the brown orchard mite, *Bryobia arborea* Morgan and Anderson, in Oregon. This mite is an economic
pest on tree fruits in The Dalles and other areas of the state.

The brown orchard mite has formerly been confused with *Bryobia praetiosa* Koch. Morgan and Anderson in British Columbia have recently shown that *Bryobia arborea* is a tree form which differs both morphologically and biologically from *B. praetiosa*, the herb form. The writer has observed the same differences between these two forms in The Dalles area.

A technique for successfully rearing individual mites on cherry and peach seedlings is presented. Individual specimens were reared in small cages made from wooden clothespins and clamped to the surface of the host plant. The activity and developmental progress of the individual mites were recorded daily. Studies of life history and habits were made by direct observation in the orchards and by bringing mites into the laboratory for observation.

The development of the brown orchard mite is related to temperature. Between 55° and 65° F., temperature seems to be the chief factor affecting the rate of development. The rate of acceleration throughout this range is almost uniform. At temperatures above 65° F. the rate of acceleration decreases and the data become more scattered, indicating that probably other factors in addition to temperature affecting development.

The three active immature stages of the brown orchard mite show similar responses to temperature; the length of the various stages are nearly the same throughout the range of temperatures measured. The length of the incubation period of the summer egg is about one
and one half times as long as the larval stage at the same temperature. The length of generations of individually reared specimens in the insectary ranged between 21 and 63 days.

The termination of diapause in the overwintering egg of the brown orchard mite was effected by exposure to 41° F. for 105 days. Diapause was not broken during exposures to 41° F., for 58 days, to 22° F. for periods between 48 hours and 118 days or to 70° F. for 165 days.

The brown orchard mite life cycle includes an egg, a hexapod larva, a protonymph, a deutonymph and an adult. Each immature stage includes a quiescent period which is terminated by moulting. This mite overwinters in the egg stage on the twigs and branches of the host. The hatching of the egg is correlated with the opening of the buds of peach and cherry trees. The first generation completes its development during May and three or four additional generations develop during the summer and early fall. The development of the first generation is sometimes retarded by cold temperatures, while the summer generations are affected by warm dry weather. The summer populations diminish during hot periods.

The brown orchard mite is a transient feeder and spends much of its life on the twigs of the host plant. In The Dalles area the first generation visits the foliage only to feed. The summer generations spend more time on the foliage. Many of them moult and deposit eggs on the leaf midribs. The immature instar usually fed only once between moults. The adults, however, are intermittent
feeders and move back and forth between leaves and twigs.

Movement of the brown orchard mite from one area of a tree to another is very slow. Often a tree will contain severe local infestations while adjacent areas remain nearly free of the mite.

In The Dalles area the brown orchard mite was found on sweet and sour cherry, peach, plum, western choke cherry, apple, and pear trees. The most severe damage to fruit trees occurs during the spring before the foliage is fully developed.

The brown orchard mite does not seem to be controlled by predators in unsprayed or abandoned orchards. In fact it is usually the most prominent of all phytophagous mites under these conditions. However, in orchards where chlorinated hydrocarbons are used in foliage sprays, populations of this mite are larger than in non-sprayed orchards. This may indicate that predators have a moderating effect on populations of this mite, since these insecticides are known to be highly toxic to many of the predators of orchard mites.
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APPENDIX
Table I

Data on the Relationship of Temperature and Development Time of *Bryobia arborea* Morgan and Anderson Larva

<table>
<thead>
<tr>
<th>Length of larval stage in days</th>
<th>Reciprocal of days x 1,000</th>
<th>Mean temperature</th>
<th>No. of mites observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.3</td>
<td>35.3</td>
<td>49.5</td>
<td>9</td>
</tr>
<tr>
<td>9.0</td>
<td>111.1</td>
<td>61.0</td>
<td>8</td>
</tr>
<tr>
<td>9.5</td>
<td>105.3</td>
<td>66.5</td>
<td>3</td>
</tr>
<tr>
<td>6.0</td>
<td>166.7</td>
<td>66.0</td>
<td>7</td>
</tr>
<tr>
<td>4.2</td>
<td>238.1</td>
<td>70.5</td>
<td>14</td>
</tr>
<tr>
<td>5.0</td>
<td>200.0</td>
<td>71.5</td>
<td>5</td>
</tr>
<tr>
<td>3.0</td>
<td>333.3</td>
<td>76.2</td>
<td>1</td>
</tr>
<tr>
<td>1956</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.2</td>
<td>122.0</td>
<td>55.5</td>
<td>20</td>
</tr>
<tr>
<td>6.5</td>
<td>153.8</td>
<td>62.0</td>
<td>27</td>
</tr>
<tr>
<td>5.4</td>
<td>185.2</td>
<td>62.5</td>
<td>16</td>
</tr>
</tbody>
</table>

Results of statistical analyses of the relationship of temperature to the reciprocal of development time.

Line of least squares

\[
X \quad Y
\]

\[
50 \quad 59.90
\]

\[
60 \quad 139.30
\]

\[
70 \quad 218.70
\]

Regression coefficient 7.94

Correlation coefficient 0.889

In figures I, II, III and IV each point on the graphs is placed inside a circle. The radius of the circle is equal to the square root of the number of observations represented by the point.
Table II

Data on the Relationship of Temperature and Development Time of *Bryobia arborea* Morgan and Anderson protonymph

<table>
<thead>
<tr>
<th>Length of protonymphal stage in days</th>
<th>Reciprocal of days X 1,000</th>
<th>Mean temperature</th>
<th>No. of mites observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.3</td>
<td>61.3</td>
<td>52.7</td>
<td>9</td>
</tr>
<tr>
<td>8.4</td>
<td>122.6</td>
<td>55.2</td>
<td>18</td>
</tr>
<tr>
<td>6.0</td>
<td>165.6</td>
<td>68.4</td>
<td>6</td>
</tr>
<tr>
<td>4.5</td>
<td>222.2</td>
<td>75.8</td>
<td>4</td>
</tr>
<tr>
<td>1956</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.0</td>
<td>112.8</td>
<td>60.6</td>
<td>13</td>
</tr>
<tr>
<td>6.4</td>
<td>156.2</td>
<td>62.5</td>
<td>21</td>
</tr>
<tr>
<td>5.5</td>
<td>181.8</td>
<td>64.2</td>
<td>10</td>
</tr>
<tr>
<td>4.3</td>
<td>232.5</td>
<td>71.5</td>
<td>7</td>
</tr>
</tbody>
</table>

Results of statistical analyses of the relationship of temperature to the reciprocal of development time.

Line of least squares: Regression coefficient 6.37

\[
\begin{array}{cc}
X & Yx \\
50 & 77.73 \\
60 & 104.93 \\
70 & 204.63 \\
\end{array}
\]

Correlation coefficient .997
Table III

Data on the Relationship of Temperature and Development Time of Bryobia arborea Morgan and Anderson Deutonymph

<table>
<thead>
<tr>
<th>Length of Deutonymphal stage in days</th>
<th>Reciprocal of days $\times 1,000$</th>
<th>Mean temperature</th>
<th>No. of mites observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.5</td>
<td>105.3</td>
<td>58.3</td>
<td>9</td>
</tr>
<tr>
<td>5.2</td>
<td>192.3</td>
<td>63.1</td>
<td>12</td>
</tr>
<tr>
<td>3.9</td>
<td>256.4</td>
<td>65.0</td>
<td>8</td>
</tr>
<tr>
<td>3.4</td>
<td>294.1</td>
<td>71.0</td>
<td>12</td>
</tr>
<tr>
<td>3.7</td>
<td>270.3</td>
<td>75.9</td>
<td>7</td>
</tr>
<tr>
<td>1956</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>153.8</td>
<td>60.1</td>
<td>8</td>
</tr>
<tr>
<td>6.4</td>
<td>156.2</td>
<td>61.5</td>
<td>11</td>
</tr>
<tr>
<td>5.5</td>
<td>181.8</td>
<td>64.0</td>
<td>20</td>
</tr>
</tbody>
</table>

Results of statistical analyses of the relationship of temperature to the reciprocal of the development time.

Line of least squares

\[
\begin{align*}
X & \quad \text{Regression coefficient} 10.68 \\
60 & \quad \text{Correlation coefficient} .893 \\
70 & \quad 246.35 \\
75 & \quad 309.75
\end{align*}
\]
Table IV

Data on the Relationship of Temperature and Development time of *Bryobia arborea* Morgan and Anderson from eclosion to adult

<table>
<thead>
<tr>
<th>Year</th>
<th>Length of immature stages in days</th>
<th>Reciprocal of days x 1,000</th>
<th>Mean temperature</th>
<th>No. of mites observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>41</td>
<td>244.4</td>
<td>55</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>52.6</td>
<td>61.4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>62.5</td>
<td>67.5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>83.3</td>
<td>71.0</td>
<td>11</td>
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<tr>
<td></td>
<td>15</td>
<td>66.7</td>
<td>72.5</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>90.9</td>
<td>74.1</td>
<td>3</td>
</tr>
<tr>
<td>1956</td>
<td>33</td>
<td>30.3</td>
<td>56.6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>47.6</td>
<td>59.3</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>58.8</td>
<td>62.4</td>
<td>9</td>
</tr>
</tbody>
</table>

Results of statistical analyses of the relationship of temperature to the reciprocal of development time.

<table>
<thead>
<tr>
<th>Line of least squares</th>
<th>Regression coefficient</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>YX</td>
<td>3.28</td>
</tr>
<tr>
<td>55=27.82</td>
<td></td>
<td>.993</td>
</tr>
<tr>
<td>60=44.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70=77.02</td>
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</tr>
</tbody>
</table>
Table V

The Percentage of Various Instars in the Populations of the Brown Orchard Mite on Stone Fruit Trees at The Dalles During 1956

<table>
<thead>
<tr>
<th>Date</th>
<th>Eggs</th>
<th>Larvae</th>
<th>Protonymph</th>
<th>Deutonymph</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/20/56</td>
<td>0</td>
<td>36.6</td>
<td>63.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5/8/56</td>
<td>23.8</td>
<td>0.33</td>
<td>1.0</td>
<td>21.8</td>
<td>53.1</td>
</tr>
<tr>
<td>5/14/56</td>
<td>82.5</td>
<td>0</td>
<td>0</td>
<td>0.2</td>
<td>17.3</td>
</tr>
<tr>
<td>5/29/56</td>
<td>62.9</td>
<td>34.3</td>
<td>1.0</td>
<td>0</td>
<td>2.0</td>
</tr>
<tr>
<td>6/12/56</td>
<td>34.7</td>
<td>9.6</td>
<td>38.0</td>
<td>10.8</td>
<td>7.3</td>
</tr>
<tr>
<td>6/23/56</td>
<td>70.4</td>
<td>1</td>
<td>3.3</td>
<td>0</td>
<td>29.4</td>
</tr>
<tr>
<td>6/29/56</td>
<td>91.5</td>
<td>3.7</td>
<td>1.4</td>
<td>0.1</td>
<td>2.4</td>
</tr>
<tr>
<td>7/10/56</td>
<td>41.0</td>
<td>6.7</td>
<td>33.1</td>
<td>11.6</td>
<td>4.9</td>
</tr>
<tr>
<td>7/19/56</td>
<td>56.3</td>
<td>0.5</td>
<td>1.9</td>
<td>11.1</td>
<td>29.4</td>
</tr>
<tr>
<td>7/26/56</td>
<td>80.5</td>
<td>4.9</td>
<td>2.9</td>
<td>1.2</td>
<td>10.4</td>
</tr>
<tr>
<td>8/3/56</td>
<td>46.1</td>
<td>21.6</td>
<td>18.6</td>
<td>7.1</td>
<td>6.6</td>
</tr>
<tr>
<td>8/11/56</td>
<td>12.7</td>
<td>6.7</td>
<td>15.7</td>
<td>27.8</td>
<td>42.0</td>
</tr>
<tr>
<td>8/21/56</td>
<td>82.7</td>
<td>2.8</td>
<td>3.2</td>
<td>4.0</td>
<td>7.4</td>
</tr>
<tr>
<td>8/31/56</td>
<td>63.2</td>
<td>8.0</td>
<td>8.8</td>
<td>6.8</td>
<td>12.7</td>
</tr>
<tr>
<td>9/7/56</td>
<td>79.3</td>
<td>1.4</td>
<td>5.5</td>
<td>6.0</td>
<td>7.8</td>
</tr>
<tr>
<td>9/15/56</td>
<td>94.0</td>
<td>0</td>
<td>4.8</td>
<td>1.2</td>
<td>4.0</td>
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</tbody>
</table>
The Effect of Various Treatments on the Termination of Diapause of Overwintering Eggs of *Bryobia arborea* Morgan and Anderson

<table>
<thead>
<tr>
<th>treatment</th>
<th>percent of viable eggs hatching at 70° F</th>
<th>7 days incubation</th>
<th>10 days incubation</th>
<th>15 days incubation</th>
</tr>
</thead>
<tbody>
<tr>
<td>check: no cold treatment</td>
<td></td>
<td>.05</td>
<td>.35</td>
<td>.42</td>
</tr>
<tr>
<td>22° F 48 hours</td>
<td></td>
<td>.16</td>
<td>1.20</td>
<td>1.30</td>
</tr>
<tr>
<td>22° F 30 days</td>
<td></td>
<td>0</td>
<td>0</td>
<td>4.10</td>
</tr>
<tr>
<td>22° F 57 days</td>
<td></td>
<td>.10</td>
<td>1.10</td>
<td>1.40</td>
</tr>
<tr>
<td>22° F 118 days</td>
<td></td>
<td>1.60</td>
<td>8.10</td>
<td>8.40</td>
</tr>
<tr>
<td>41° F 58 days</td>
<td></td>
<td>1.70</td>
<td>4.50</td>
<td>11.00</td>
</tr>
<tr>
<td>41° F 105 days</td>
<td></td>
<td>15.70</td>
<td>99.40</td>
<td>100.00</td>
</tr>
<tr>
<td>41° F 150 days</td>
<td></td>
<td>70.60</td>
<td>86.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>
Figure I
Temperature-developmental time relationships for *B. arborea* larvae
Figure II

Temperature-developmental time relationships for *B. arborea* protonymph
Figure III
Temperature-developmental time relationships for *B. arborea* deutonymph

Temperature in °F.

1,000/development time in days

Development time in days

Temperature in °F.
Figure IV
Temperature-developmental time relationships for *B. arborea* from eclosion to adult.

- Indicated reciprocal relation
- Reciprocal curve
- Line of least squares
Figure V
Percent of eggs and adults in populations of the Brown Orchard mite on cherry trees during the 1956 season.
FIGURE VI.

LARVA

PROTONYMPH
Figure VIII
Peritremes of the different instars of *Bryobia arborea*

Protonymphal peritreme

Larval peritreme

Deutonymphal peritreme

Imaginal peritreme
Figure IX
Materials used in individual rearing studies of *Bryobia arborea*

Cages used to retain mites

Cage on cherry leaf

Potted seedling cherry showing rearing cages and supports

Supports for cages and microscope