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THE NATURE AND EXTENT OF ERIOPHYES VITIS INJURY TO VITIS VINIFERA L. 1

BY

Leslie M. Smith 2 and Robert O. Schuster 3.

Following the description of Eriophyes vitis (Pagenstacher, 1857) there have appeared a number of papers dealing with the relationship between the mite and its only known host, Vitis vinifera. The most encompassing of these are the papers by Smith and Stafford (1948) in which three strains of E. vitis are recognized and the resulting injury characterized, and by Kido and Stafford (1955) in which the biology of the mite is considered.

The present study describes the pathological symptoms produced by mite feeding and relates these to the resulting gross structural malformations. Some factors regulating the abundance of the mites are also noted.

Pertinent facets of the annual cycle are as follows: The mites overwinter in dormant buds. At the initiation of spring growth, the mites have started to reproduce and may infest, to some degree, the entire developing shoot. Soon most of the mites are restricted to parts of the shoot offering concealment, usually the basal bud scales and stipular scales but sometimes the clusters or shoot apex. Infrequently, large numbers of mites have been observed living openly on shoots, in the spring, in commercial vineyards.

The ovary of an adult female (fig. 2 A) contains eight or more eggs in successive stages of development and these are laid at the rate of about one a day. The incubation period is approximately six days. The adult stage is reached about 14 days after the egg hatches. Predation, weather, spray programs and physical limitations on space are probably the most important factors controlling population increase. Large buds occurring on canes of large diameter can contain thousands of mites while very small buds on canes of small diameter can, naturally, hold fewer mites — undoubtedly a contributing factor in the occurrence of injury. The mites infest the developing buds as soon as they offer protection and usually remain there until the next growing season.

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2. Entomologist and.
3. Laboratory technician, Department of Entomology, University of California, Davis.

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The intensity of the manifestations of mite injury is variable, due in large part
to differences in the population density between individual buds, and to fluctuations
in the yearly abundance of mites. Thus the frequency of occurrence of
symptoms is useful in distinguishing mite injury from other syndromes which
affect all shoots of a vine in a uniform manner.

No instances of diseases of these mites, either fungal, bacterial, or viral have
been noted. Infrequently, large numbers of dead mites were found enclosed in
dead overwintering buds and in the absence of succulent tissue. These presum­
ably died of starvation.

Examples of various mite infested tissues and structures were sectioned and
stained. The varieties Carignane and Tokay were studied, both from commer­
cial vineyards and greenhouse cultures. These were examined microscopically
to determine the effect of mite feeding on tissues in order to better understand the
resulting gross symptoms. From these studies it was noted that the feeding by
E. vitis usually produces at first a hypertrophy of the cells in the immediate area
(fig. 1A). The chemical substance involved apparently is not translocated as
adjacent cells remain normal. The hypertrophied cells remain active and eventu­
ally subdivide. Areas of these enlarged cells form the polyps, characteristic
of mite feeding as seen at low powers of magnification. Cells of meristematic
tissue frequently undergo periclinal divisions to form a wound-healing tissue.
The mouthparts of the mites have been observed to enter only the outermost
cell, either epidermal or modified epidermal (polyp) cell.

Grape buds form in the axils of the leaves in the dormant bud. As the new
shoot elongates in the spring the buds lie between two stipular scales that were
part of the overwintering bud. If mites were present on those stipular scales,
they may easily move into the new bud developing there. In fact, injury to the
bud primordia frequently occurs in the overwintering bud. There is a distichous
arrangement of leaf primordia with the basal leaves forming at the base of the bud
and associated with the outer stipular scales. The fruit primordia and the more
apical leaves are progressively distal and deeper in the bud. Mites normally enter
the bud and establish colonies under the bud scales or the outermost stipular
scales. Therefore, the greatest amount of feeding and damage occurs on the basal
leaves of the embryonic shoot. Larger populations work progressively deeper in
the bud and the depth of penetration as well as the size of the population is reflec­
ted in proportional damage to new shoot growth. (See Table III for effect of
increasing population, and Table IV for effect of depth of penetration).

**MITE INJURY TO BUD SCALES AND STIPULAR SCALES OF OVERWINTERING BUDS.**
When the mites feed on either surface of a scale they cause hypertrophy of the
epidermal cells and the formation of polyps. These polyp cells are thin walled
and may increase to 20 to 30 times the size of a normal cell. Polyp cells are
nucleate and usually vacuolate. These hypertrophied cells may divide, and for
older polyps a cork-like layer may be found although wound-healing tissue resul-
ting from orderly periclinal cell division has not been seen. Extensive populations can feed on scales during the fall and winter apparently without necessarily affecting the shoot when it develops in the spring. This does not obtain, however, if the mites feed on various structures of the shoot primordia. Severely damaged buds appear discondite, with the bud scales wrinkled and often more grey in color than undamaged buds.

**Mite injury to shoot apex.** Mites feeding on the tunica layer first produce hypertrophied initial cells that disrupt the organization of the apex (fig. 2 B). Wound-healing tissue forms under the enlarged initial cells and the periderm thus formed interferes, for a time, with continued shoot elongation. Badly damaged shoot apices, then, are short and thick (fig. 2 A) in contrast to normal shoot apices (fig. 2 B) which exhibit a more open growth habit. If the scar tissue is extensive, one or more lateral bud primordia initiate growth. If these are already damaged a secondary or tertiary growing point may produce a cane. This may often result in witches-broom or zig-zagged canes. If shoot growth is retarded and the mite population is sufficient to kill the shoot, this usually occurs before the shoot is two or three inches in length. The smaller, secondary and tertiary growing points in the overwintering bud are infested infrequently and may give rise to a normal cane, even though the shoot from the primary growing point is killed by mites.

**Mite injury to the bark.** Immediately beneath and often for a short distance above scales concealing large mite populations, small areas of scar tissue are commonly in evidence. These areas of scar tissue are of a finer texture than would result from, for example, thrips feeding, and are often composed of numerous irregular shaped scars interspersed on relatively normal epithelium.

**Mite injury to flower clusters.** Mites feeding in flower primordia at first produce slight enlargement of the cells (and intensified reaction to stains). Typical polyp formation is most noticeable along the peduncles and bracts. Severe injury to flower buds leaves only a shell formed by the calyx and at times also the anthers (fig. 4 B). Dead cluster branches appear to be dry and discolored, and when damage is extensive, the entire cluster usually will abscise before bloom.

**Mite injury to leaves.** Mites feeding on embryonic leaves first cause hypertrophied epidermal cells which later form scar tissue. These scar areas (fig. 5 A) are incapable of resuming normal development and result in disruption or coalescence of venation, cut leaf margins, and generally misshapen appearance of the leaf at maturity (fig. 1 B). Necrotic spotting, uniform crinkling of leaves or open petiolar sinuses are not normally expressions of mite damage.

Parenthetically it may be stated that the effect on the vine produced by the erinose strain of *E. vitis* was also studied. Erinia were fixed, sectioned, and examined microscopically with the idea that information from this source might further illuminate the effects produced by the bud strain. It was found that in
the formation of the erinose gall, epidermal cells are stimulated to growth somewhat resembling plant hairs (fig. 5 B). These cells are larger and of more irregular shape than normal plant hairs and are not tapered at their apices. They are nonseptate and usually contain deeply staining, granular cytoplasm. They are abundant and are normally associated with a concavity (gall) of the lower leaf surface.


In order to study the syndrome of *E. vitis* injury, and the extent of this injury in a greenhouse, the following experiment was performed. A uniform group of 100 mite free cuttings of Tokay vines were planted individually in 100 eight-inch flower pots in Yolo clay-loam. All factors, such as watering, were held as uniform as possible. Fifty of these vines were infested by hand when their buds reached the cabbage-head stage of development, by placing stipular scales from infested vines into the developing buds. Uninfested scales were inserted in the buds of the uninfested vines to equalize possible mechanical injury. Although this method of infesting the vines was successful, it was impossible to control the size of the resulting populations, and some of the infested vines became more heavily infested than others. The 50 noninfested vines remained free from mites throughout the experiment. At five different times during the growing season the lengths of all shoots were measured and these data are summarized in Table I.

**Table I**

Mean length in inches of shoots, infested and noninfested Tokay rootings, bench-grown in a greenhouse, Davis, California.

<table>
<thead>
<tr>
<th>Date</th>
<th>Infested</th>
<th>Noninfested</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb. 28</td>
<td>1.7 ± 1.5</td>
<td>1.7 ± 1.0</td>
<td>—</td>
</tr>
<tr>
<td>May 5</td>
<td>2.6 ± 1.0</td>
<td>6.4 ± 1.5</td>
<td>&gt; 0.10^1</td>
</tr>
<tr>
<td>May 21</td>
<td>2.9 ± 1.1</td>
<td>9.8 ± 2.7</td>
<td>0.01</td>
</tr>
<tr>
<td>July 2</td>
<td>18.4 ± 8.3</td>
<td>36.8 ± 7.5</td>
<td>0.01</td>
</tr>
<tr>
<td>Sept. 25</td>
<td>30.7 ± 7.8</td>
<td>40.3 ± 7.4</td>
<td>&gt; 0.10</td>
</tr>
</tbody>
</table>

Although not expressed in Table I, much of the growth recorded for the infested group was from lateral buds, as many of the original or primary growing points had been killed when the shoots were between two and three inches in length. Examples were noticed in which auxiliary buds of a shoot were forced four successive times as a result of repeated loss of growing points.

1. Significance is based on Student's values comparing infested and noninfested canes for any one date.
The frequency of occurrence of five symptoms was observed during an experiment similar to the one described above. In this growing period the mean shoot length was significantly shorter for the infested plants. The data from this experiment is summarized in Table II. From the data it can be seen that abnormal basal leaves were the most frequent symptom. The occurrence of such malformed basal leaves appears also to be the commonest character for recognition in the field of early growth. Abnormal basal leaves are characterized in the paragraph entitled: "Mite Injury to Leaves".

### Table II

Frequency of Occurrence of Symptoms on Tokay Shoots, potted vines in a greenhouse.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Fifty-five mite infested shoots</th>
<th>Fifty-four noninfested shoots</th>
<th>Probability based on X²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Per Cent</td>
<td>Number</td>
</tr>
<tr>
<td>Abnormal basal leaves.............</td>
<td>24</td>
<td>43.7</td>
<td>5</td>
</tr>
<tr>
<td>Short, thick basal internodes....</td>
<td>6</td>
<td>10.9</td>
<td>0</td>
</tr>
<tr>
<td>Dead growing point................</td>
<td>7</td>
<td>12.7</td>
<td>0</td>
</tr>
<tr>
<td>Forced auxiliary buds.............</td>
<td>15</td>
<td>26.4</td>
<td>4</td>
</tr>
<tr>
<td>Zig-zagged shoots.................</td>
<td>3</td>
<td>5.5</td>
<td>0</td>
</tr>
</tbody>
</table>

Description and Extent of Injury Under Field Conditions.

A. A block of ten-year old Carignane vines at Davis was analyzed in the spring of 1960. A random sample, examined microscopically during the previous winter showed 70% of the buds were infested. Of 472 shoots observed in the field in the spring of 1960, 19 or about 4% evidenced severe mite injury. Of a random sample examined in the laboratory, 245 of 326 shoots (75%) were found to be infested to some degree. Four characteristics of these shoots were measured and the total mite population per shoot was then ascertained by dissection. The data obtained, classed by degree of infestation, are given in Table III. Significance, based on Student's values, are at the 0.01 level except for weight of flower clusters between light and medium, and medium and heavy infestations where the probability level was 0.10.

An additional sample of shoots with one or more mite injured leaves was collected and the data obtained were added to that on which Table III was based. These combined data are given in Table IV. The number of mite injured leaves is a reflection of the size of the mite population with an average of one mite inju-
TABLE III
Effect of mite populations on Carignane shoots, according to the degree of infestation.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Degree of Infestation, Mites per Shoot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uninfested</td>
</tr>
<tr>
<td>Shoot length in inches</td>
<td>13.7 ± 4.6</td>
</tr>
<tr>
<td>Length of first six nodes</td>
<td>9.2 ± 1.9</td>
</tr>
<tr>
<td>Mite-injured leaves per shoot</td>
<td>0.0</td>
</tr>
<tr>
<td>Weight of flower clusters in grams</td>
<td>3.56 ± 3.0</td>
</tr>
<tr>
<td>Number of shoots in sample</td>
<td>82</td>
</tr>
</tbody>
</table>

red leaf resulting from a mite population in the low hundreds (see Table III). As the number of mite injured leaves increases, the shoot length of first six nodes and the weight of forms decreases. The first six nodes account for a greater percentage of the length of the heavily infested shoots as there is frequently no growth beyond the sixth or seventh nodes.

TABLE IV
Growth characteristics classed by number of mite injured leaves per shoot, on Carignane vines.

<table>
<thead>
<tr>
<th>Number of mite injured leaves per shoot</th>
<th>Shoot length in inches</th>
<th>Length of first six internodes</th>
<th>Weight of forms in grams</th>
<th>Number of examples in class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.5</td>
<td>5.5</td>
<td>2.9</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>5.9</td>
<td>3.6</td>
<td>1.1</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>3.7</td>
<td>3.0</td>
<td>0.4</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>2.0</td>
<td>1.4</td>
<td>0.0</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>1.2</td>
<td>1.1</td>
<td>0.0</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>1.1</td>
<td>0.9</td>
<td>0.1</td>
<td>11</td>
</tr>
</tbody>
</table>
B. The following experiment was conducted in a commercial Tokay vineyard. The vines were considered to be essentially the same in respect to age, vigor, etc. A section of 456 vines was determined (winter I) to be rather uniformly infested. This section was subdivided into a block of 120 vines (in excess of 1,800 potential canes) and a block of 336 vines (in excess of 5,000 potential canes). The mite population was removed chemically from the larger block (Spring I) but not from the smaller. The effectiveness of the chemical control was ascertained (winter II) by dissection of buds as 0 per cent where treated, and 30 per cent in the control area. Shoot development (spring II) was observed and those showing considerable mite injury had the presence of mites confirmed by dissection.

In April, when the length of shoots in the uninfested block averaged 7.2 inches (341 shoots measured) shoots in the infested block (370 measured) averaged only 6.1 inches. A count of flower clusters showed an average of 19 per vine in the noninfested block, 10% more than in the infested block. Thus, differences were measured where the only apparent variable was the presence or absence of mites.

In order to evaluate the effect of mite populations on individual shoot growth and crop development, a sample of shoots showing obvious infestation and a control group of shoots lacking signs of mites were tagged with metal strips when shoot lengths averaged 10 inches. Infested and noninfested shoots were chosen from the same vines. On July 28, 37 of the noninfested and 48 of the mite infested canes were measured. The best cane arising from each bud was finally recorded although a dead primary shoot occasionally indicated that the measured cane was not the one originally tagged, but a cane growing from a secondary growing point in the original bud. The measurements obtained are summarized in Table V. The t value between the length of the first six nodes is 23.97; with 84 d.f., the significance is 0.01.

| Table V |
| Effect of Early Season Mite Populations on Tokay Canes and Crop. |

<table>
<thead>
<tr>
<th></th>
<th>Length of first six internodes</th>
<th>Length of second six internodes</th>
<th>Number of canes with crop</th>
<th>Total number of canes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noninfested</td>
<td>13.5 ± 3.2</td>
<td>18.9 ± 3.6</td>
<td>35</td>
<td>37</td>
</tr>
<tr>
<td>Infested...</td>
<td>4.7 ± 2.0</td>
<td>11.6 ± 7.0</td>
<td>10</td>
<td>48</td>
</tr>
</tbody>
</table>

The tagged canes from the experiment described above were removed when dormant in the fall and examined in the laboratory. The data contrasting the two groups of canes, one having resulted from shoots not showing injury in the spring, and the other from injured shoots, is given in Table VI.
TABLE VI

<table>
<thead>
<tr>
<th>Canes resulting from shoots without injury</th>
<th>Mean cane diameter, in millimeters</th>
<th>Number buds dissected</th>
<th>Number buds infested</th>
<th>Mean number mites per infested bud</th>
<th>Number dead buds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.2</td>
<td>84</td>
<td>43 (57 %)</td>
<td>186</td>
<td>1 (1.2 %)</td>
</tr>
<tr>
<td>Canes resulting from mite injured shoots</td>
<td>7.5</td>
<td>98</td>
<td>61 (62.3 %)</td>
<td>78</td>
<td>22 (22.4 %)</td>
</tr>
</tbody>
</table>

Symptoms somewhat similar to those of *E. vitis* injury responded to boron (Barnes, 1958), and this raised the question of whether boron level would also influence mite injury. In cooperation with Dr. J. A. Cook, an experiment was conducted to determine the effect of the boron level. Carignane cuttings grown in quartz sand were watered with a nutrient solution containing 3-4 ppm. boron and another group of shoots were given the same nutrient solution, but without boron. The boron treated groups eventually showed signs of boron toxicity. The occurrence of symptoms is given in Table VII.

TABLE VII

Occurrence of mite symptoms on Carignane shoots with high and low boron content.

<table>
<thead>
<tr>
<th>Group 1</th>
<th>1B</th>
<th>2</th>
<th>3B</th>
<th>4B</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of shoots</td>
<td>24</td>
<td>21</td>
<td>23</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Number of shoots with mite injury</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>Treatment produced syndrome of boron toxicity</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

1. The groupings indicate the following: 1B Low percentage of dormant buds infested, low previous boron level, boron applied in nutrient solution. 2) Low percentage of dormant buds infested, low previous boron level, boron not applied in nutrient solution. 3B Low percentage of dormant buds infested, high previous boron level, boron applied in nutrient solution. 4B) One hundred percent of dormant buds infested, previous boron level unknown, boron applied in nutrient solution. 5) One hundred percent of dormant buds infested, previous boron level unknown, boron not applied in nutrient solution.

From this experiment the following observations were made. 1) Boron concentration
Factors influencing the population density of *E. vitis* are considered to be:

1) Cultural. For head pruned varieties, a large percentage of the total population of mites is annually removed from the vines. Unfortunately for the grower, this does not alter the percentage of infested buds remaining.

2) Biological. Phytoseiid mites are the most effective predators. A single female of *Metaseiulus occidentalis* has been observed to destroy 100 *E. vitis* in a 24-hour period. One or two predators, at the cabbage-head stage of bud development would be sufficient to decimate a normal sized population. The adult female is restricted in movement by its size. The larva does not feed but the proto- nymph does feed and its small size allows access to *E. vitis* even in the most remote locations.

   Predatory mites overwinter under the bark, in abscission tissue or under bud scales. Their numbers fluctuate considerably and very large populations of overwintering individuals occur infrequently. The number of predators available in the spring might be influenced mainly by the abundance of prey (red-spiders) present in the fall and by the extent of winter mortality. However unstable the populations and sporadic the occurrence of predaceous mites, *E. vitis* populations are usually lowered by these predators.

3) Chemical. In the spring, when shoot length is 12-18 inches, *E. vitis* is more exposed than at any other time. The bud scales of the overwintering buds are loosely appressed to the shoot, the stipular scales offer scant protection except in a small basal area, and the new buds are represented by little more than the embryonic bud scales. A number of pesticides, applied at this stage of shoot development, have been observed to considerably reduce mite populations.

**SUMMARY.**

*Eriophyes vitis*, feeding on embryonic tissue of grape buds or shoots, causes hypertrophy of the cells fed upon and later, the formation of scar tissue. This injury, when extensive, results in malformation of the maturing structure. Other organisms or conditions interfering with the normal maturation of tissue may account for deformations similar to those produced by *E. vitis* feeding.

The possibility of economic losses due to *E. vitis* is normally minimized by the propensity for the mites to feed primarily on the scales of overwintering buds and by the reduction of their numbers on new shoot growth by factors such as predation and possibly climate. *E. vitis* injury in commercial Tokay vineyards which were studied did not cause a commercial loss. However the effect on vine in the shoots sufficient to cause boron toxicity symptoms had little or no adverse effect on mite populations. 2) Mites were able to cause typical injury to shoots with high as well as low boron content. 3) The symptoms produced by the mites were distinct from those produced by boron excess. The classic symptoms of boron excess syndrome were identified by Dr. J. A. Coox, and the syndrome of mite injury was identified by the authors.
**Fig. 1A.** — Section through stipular scale and embryonic leaf. Polyp cells restricted to inner surface of scale.

**Fig. 1B.** Severely damaged shoot with typical mite injury on the large leaf (upper margin).

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Fig. 2A. — Section through gravid female of *E. vitis*.

2B. Median section of shoot apex damaged by bud mites. Polyp cells and periderm have obscured normal organization.
Fig. 3A. — Shoot apex infested with bud mites.

3B. Uninfested shoot apex. Both examples produced under greenhouse conditions.
Fig. 4A. — Section through uninfested flower primordia.

4B. Section through mite-infested cluster primordia.
Fig. 5A. — Part of embryonic leaf with areas of scar tissue densely stained.

5B. Section through erinose gall.
growth of small populations can be measured and greater injury would obviously be expected from epidemic mite populations.

Boron level in the vine appeared to have no effect on bud mite populations nor on the injury inflicted by the mites.

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