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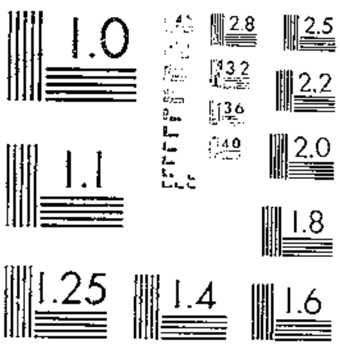

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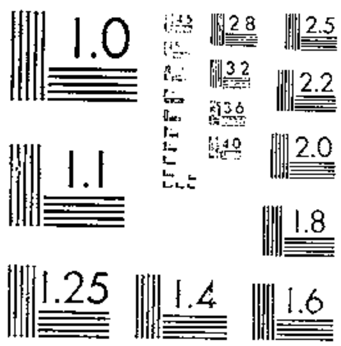

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BIOLOGY AND CONTROL OF TREE HOPPERS INJURIOUS TO FRUIT TREES IN THE PACIFIC NORTHWEST

BY

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UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D.C.

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By M. A. YOTHERS, *associate entomologist, Division of Fruit Insects, Bureau of Entomology*

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INTRODUCTION

In recent years considerable injury has been done to young orchard and nursery trees in certain parts of the Pacific Northwest by the egg-laying activities of various species of Membracidae, commonly known as "tree hoppers." This injury was of such importance that life-history studies and control experiments were begun at the Yakima, Wash., laboratory of the Bureau of Entomology in 1923 and continued until 1928.[1] The present bulletin gives the results of these biological studies, orchard observations, and control experiments.

Until quite recently the tree hoppers in orchards of the Pacific Northwest have been referred to indiscriminately by both entomologists and orchardists as the "buffalo tree hopper", although Wilson *(31)*[2] in 1915 and Lovett *(18)* in 1923 reported on certain other species. During the course of the author's studies, however, it developed that there are present in Washington, Oregon, and Idaho 15 or more

[1] The observations on *Heliria rubidella* were made at Wenatchee, Wash., from 1928 to 1932, with the assistance in 1930–32 of Paul B. Allen, Jr.

[2] Italic numbers in parentheses refer to Literature Cited, p. 44.

species of the genera *Stictocephala* and *Ceresa*, of which *S. inermis* Fab., *C. basalis* Walk., and *C. bubalus* Fab. are the more common and the ones responsible for the injury to fruit trees.

Studies and control experiments were confined largely to *S. inermis* and *C. basalis*, with minor observations on *C. bubalus*, *C. albidosparsa* Stål, and *Heliria rubidella* Ball.

The normal food plants of the tree-hopper nymphs appear to be certain succulent herbaceous plants and not fruit trees. Hodgkiss (*17*), in discussing the Membracidae in general, states that the young stages require more succulent foods. He reared nymphs through the earlier stages on young apple and pear trees, but in their later stages they became restless and were then fed upon other succulent, tender plants, principally the thistle.

STICTOCEPHALA INERMIS FAB.

DISTRIBUTION

Stictocephala inermis is the most common of all the membracids found in the orchards of the Pacific Northwest. It is probably more or less generally distributed throughout the States of Washington, Oregon, and Idaho wherever suitable environmental conditions prevail. Where acceptable food plants and suitable wood for the deposition of eggs are present and where climatic factors are favorable, as in the orchards of the arid districts, in which cover crops of alfalfa are grown, it becomes sufficiently abundant to be of economic importance.

This species is found generally throughout most of the United States, except in the Southeast, and is also present in the Canadian Provinces bordering on the United States.

SYNONYMY AND COMMON NAME

This species was originally described by Fabricius (*7, p. 677*) and placed in his genus *Membracis* in 1775. In 1830 Say (*24, p. 243*) described it as *goniphora* of the same genus. Fitch, in 1851 (*11, p. 48*), referred *inermis* Fab. to the genus *Smilia* of Germar. Walker (*29, p. 1141*), in 1852, placed Say's species in the genus *Ceresa* of Amyot and Serville. In 1869 Stål (*26, p. 246*) placed *inermis* in his new genus *Stictocephala*. Rathvon (*23, p. 551*) in the same year used the same specific determination but placed it in Germar's *Smilia* (misspelled as *Smillia*). Since Uhler (*27, p. 471*), in 1871, placed the species back in the genus *Stictocephala* of Stål (spelling it as *Stictocephalus*) it has retained that classification.

The more important discussions of *inermis* are by Hodgkiss (*17*), Funkhouser (*12, 13*), and the writer (*32, 33, 34*). This species was under discussion by the writer (*32*) under the name of *pacifica* Van Duzee.

Stictocephala inermis has been called the "green clover tree hopper" by the writer (*33*) and others.

The more important synonymy is as follows:

Membracis inermis Fabricius, 1775 (*7, p. 677*)
Membracis goniphora Say, 1830 (*24, p. 243*)
Smilia inermis Fitch, 1851 (*11, p. 48*)
Ceresa ? goniphora Walker, 1852 (*29, p. 1141*)
Stictocephala inermis Stål, 1869 (*26, p. 246*)
Smillia inermis Rathvon, 1869 (*23, p. 551*)
Stictocephalus inermis Uhler, 1871 (*27, p. 471*)

FOOD PLANTS

In the Northwest the author has found the nymphs of *S. inermis* almost exclusively on alfalfa (*Medicago sativa*), and in the earlier stages they are invariably found as far down within the crown of the alfalfa plants as they can get. At such points the plant is succulent, direct sunlight is cut off, and the maximum humidity prevails. Some have been found upon sweetclover (*Melilotus* spp.), and a few in the earlier stages have been found feeding on dandelion (*Taraxacum officinale*) and upon a species of wild mustard. In one infested orchard in which there were scattering alfalfa plants, all of which were heavily infested, extensive sweeping failed to reveal the presence of any of the insects in a thick growth of green foxtail (*Setaria viridis*). Funkhouser (*12*) records this tree hopper as common on sweetclover and red clover (*Trifolium pratense*) and occasionally on timothy (*Phleum pratense*). Essig (*6, p. 205*) regards it as common and often injurious to grasses, alfalfa, sweetclover, and other forage plants and weeds. Since alfalfa is an introduced species, it is obviously not the original food of this tree hopper, and the insect must have transferred its attention to this plant in recent years. Nymphs placed by the author upon opening apple leaf buds fed upon them to a certain extent, but all died within 9 days.

CHARACTER AND IMPORTANCE OF INJURY

The injury to fruit trees caused by *Stictocephala inermis* is the result of the numerous punctures made in the bark and outer wood in the process of egg laying. Twigs in which eggs have been laid have a characteristic roughened, ragged appearance (pl. 1, *A*, *B*, and *D*; pl. 6, *A*, *c*).

Most of the egg laying is done in the older wood of the previous season's growth, but the roughened condition persists for 2 or 3 years, after which time the curled fragments of bark wither, leaving only the deeper wounds and healed scars, giving the bark a slightly lumpy appearance. On peach twigs, injury by *S. inermis* causes gum to ooze from the wounds. This gum hardens into a dark, brittle exudate, giving the bark the appearance shown in plate 1, *C*.

The injury caused by this species occurs rather generally in apple and pear orchards in the Pacific Northwest wherever alfalfa is grown as a cover crop, occasionally in peach and willow trees, and on rare occasions in prune and poplar. The injury is particularly important in 1-year-old and 2-year-old apple and pear trees. In older trees the injury is largely confined to the twigs or smaller branches within 6 or 7 feet of the ground, especially where the branches hang well down into or toward the alfalfa.

The nymphs cause moderate injury to alfalfa by sucking out the plant juice in such a manner as to give the stems a girdled appearance (pl. 2, *C*). Wildermuth (*30*) has described similar injury to alfalfa by *Stictocephala festina* Say, but in the Northwest the damage done by *S. inermis* and other species to alfalfa has been found by the writer to be comparatively unimportant.

DESCRIPTION OF STAGES

THE EGG

The egg (fig. 1, *A*) is about 1.5 mm in length and 0.4 mm in diameter. White, apex slightly pink; roughly cylindrical, compressed latterly toward apex, broadly expanded below, bluntly rounded at the base; margins more or less curved; chorion vitreous, transparent.

THE NYMPH

The nymphs have much the same general shape as do the adults, but the body, instead of being covered by the prothoracic shield, is covered with many tuberosities, spines, and hairs. There is 1 pair of these dorsal tuberosities on the head, 2 pairs on the prothorax, 1 pair each on the mesothorax and metathorax, none on the first abdominal segment, but 1 each on the 7 succeeding abdominal segments.

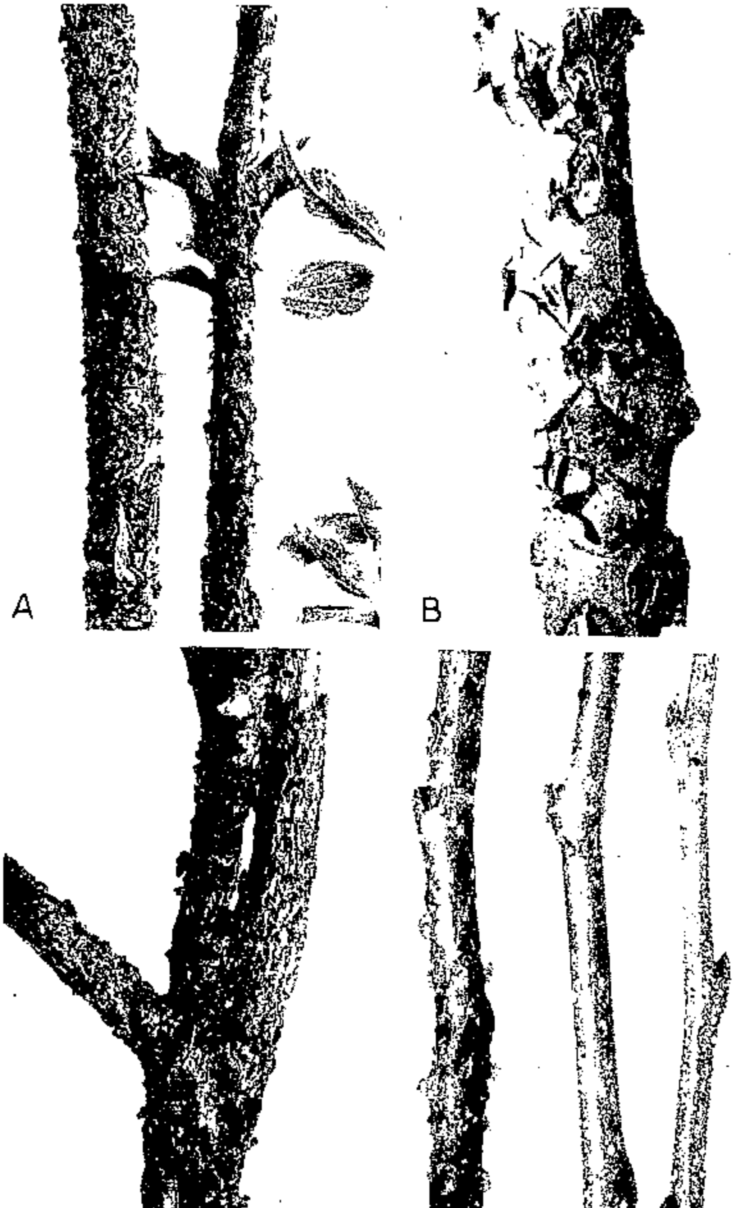
The number of tuberosities does not appear to be specific, as Wildermuth (*30*) figures the same for *S. festina* and Hodgkiss (*17*) describes the same number of tuberosities for *C. bubalus*, *C. taurina* Fitch, and *C. borealis* Fairm. The general appearance of the nymphs remains about the same throughout the five instars, except that in the first the dorsal tuberosities have but a single subspine, whereas later instars have multiple-branched tuberosities. Also, of course, the wing pads develop during the fourth and fifth instars (fig. 1, *E* and *F*).

DESCRIPTION OF INSTARS

First instar (fig. 1, *B*).—Length 1.5 to 2 mm. Head compressed cephalocaudad, oblique and rounded in front, mouth parts directed backward and reaching the middle of the second abdominal segment. Eyes white with dark center from which arise three stout, simple hairs. One pair of unbranched tuberosities on apex of head, ending in long, slender, slightly recurved hairs; several pairs of hairs on head and face, those on the upper part of the head curving upward, those on the face curving downward. Prothorax with two pairs of tuberosities, the front pair unbranched, the second pair with a single stout spine in addition to a long spine terminating each tuberosity. Mesothorax with a single pair of tuberosities with two short spines branching off (fig. 2, *A*, *a*). Metathorax with a single 1-branched tuberosity. First abdominal segment with no tuberosity, but instead a small, simple hair. Succeeding abdominal segments each with a pair of single-spined tuberosities in addition to the long hair terminating each, sloping and curling caudad, overlapping the succeeding one. Anal tuberosity smaller and with two short spines at its base. Three or four hairs on either side of each thoracic and abdominal segment. Hairs fringing end of anal segment. Color: White when first hatched, but after an hour or so turning to pale straw color and then to purplish brown on head and part of thorax and abdomen, body generally hyaline, tuberosities slightly suffused. Legs pale.

Second instar (fig. 1, *C*).—Length 2.5 to 3 mm. Head compressed cephalocaudad, rounded, spinose, reaching to the first abdominal segment. Tuberosities complex. Eyes supporting three hairs, single pair of complex tuberosities at apex of head with two branches, hairs on face and head as in first instar. Prothoracic tuberosity with 4 subspines (fig. 2, *C*). Mesothoracic, metathoracic and abdominal (fig. 2, *D*) dorsal tuberosities each with from 6 to 7 subspines, except anal tuberosity, which has but 2. More median hairs on sides of segments throughout. Anal tube fringed with spines and hairs. Color: Body generally hyaline; head and prothorax darker than in first instar, especially along dorsum and at spots along sides and on legs.

Third instar (fig. 1, *D*).—Length 3.5 to 4.5 mm. Head somewhat compressed cephalo-caudad, but less than in earlier instars. Tuberosities and hairs on head as before. Prothoracic subspines large, 6 in number, and stout (fig. 2, *E*). Mesothoracic, metathoracic, and abdominal tuberosities with about 10 subspines each (fig. 2, *F*). Tuberosity subspines intermingling. Abdominal tuberosities curving backward, last pair not reaching the anal pair, which are smaller and with only 3 or 4 subspines. Thoracic and abdominal hairs short and stout. Body spinose. Color: Hyaline to pale greenish on head, dorsum, and spots along sides. More color than in preceding instars.



INJURY TO FRUIT TREE TWIGS BY STICTOCEPHALA INERMIS

A, Apple twigs showing characteristic shaggy, roughened appearance caused by the oviposition wounds. $\times \frac{2}{3}$. B, The same, twice natural size. C, Injury to young peach tree showing protruding particles of dark, brittle exudate formed by the sap oozing from the wounds. $\times \frac{3}{4}$. D, Characteristic curling back of outer bark at oviposition scars in pear twigs. $\times \frac{2}{3}$. Note that only two scars appear in the newer wood in the center and none in the still younger growth at the right.

A and B, Egg pouches of *Stictocephala inermis* with bark removed showing the arrangement of the eggs. × 1.6. C, Alfalfa stems showing scars caused by the feeding of nymphs of *S. inermis* confined in rearing cages. × 3/4. D, Empty hatching membranes protruding from egg pouches of *S. inermis*. × 1.3. E, Nymphs of *S. inermis* issuing from eggs in apple twigs. × 1.3.

Fourth instar (fig. 1, *E*).—Length 5 to 5.5 mm. Head compressed cephalocaudad, but less than before. Eye spines several. Body curved, spinose. Mouth parts horizontal, reaching to metathorax only. Wing pads conspicuous.

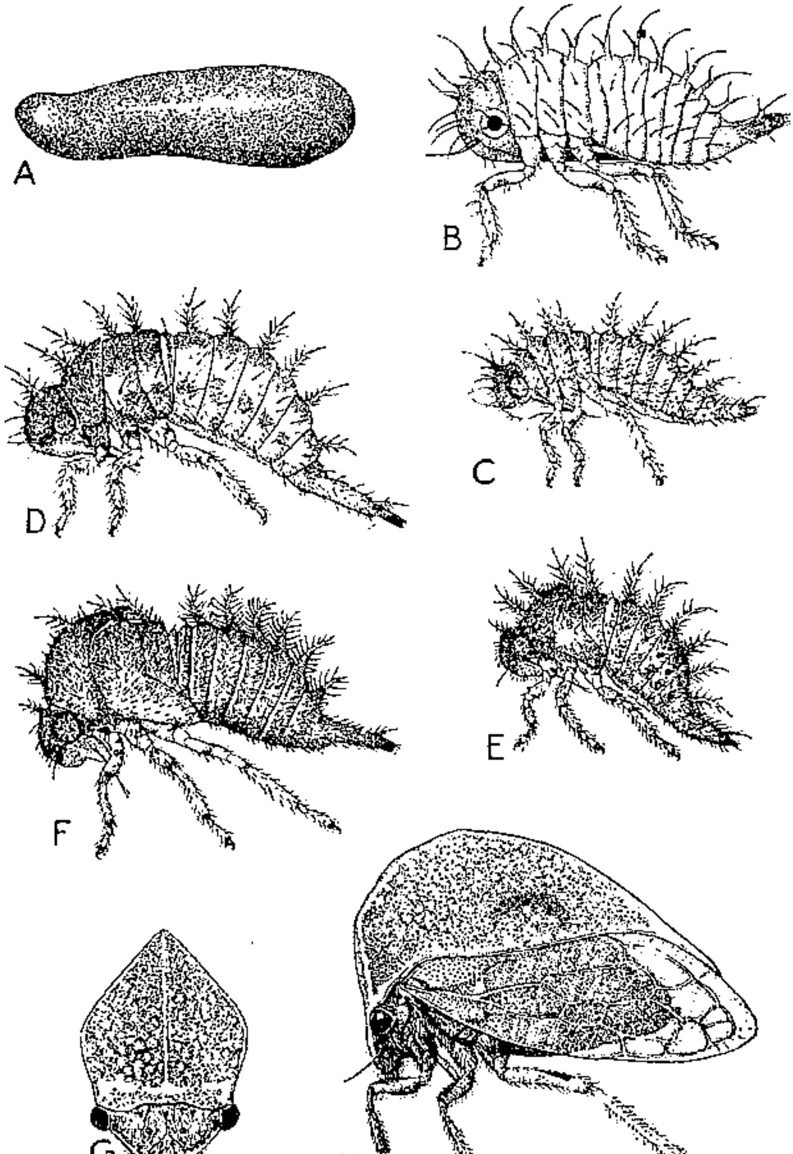


FIGURE 1.—Successive stages in the development of *Stictocepha* *nermis*: A, Egg, ×30; B-F, first to fifth nymphal instars, B×25, C×13, D×15, E×7, F×7; G, adult, at view, ×7; H, adult, side view, ×7.

Thoracic and abdominal tuberosities with 15 to 22 subspines (fig. 3, *A* and *B*), tuberosities broader at base, extending the whole width of segment. Abdominal tuberosities strongly curved caudad, subspines intermingled. Color: Brownish testaceous on head, dorsum, and median part of thorax, with spots of brown on each abdominal segment. Tuberosities somewhat suffused.

Fifth instar (fig. 1, *F*).—Length 7 to 8 mm. Head compressed caudad, but less than formerly. Ventose. Eye spines numerous. Prothorax strongly elevated, keel sharply rounded; hooked, spinose. Thoracic tuberosities leaning forward, abdominal tuberosities leaning forward but curving strongly backward.

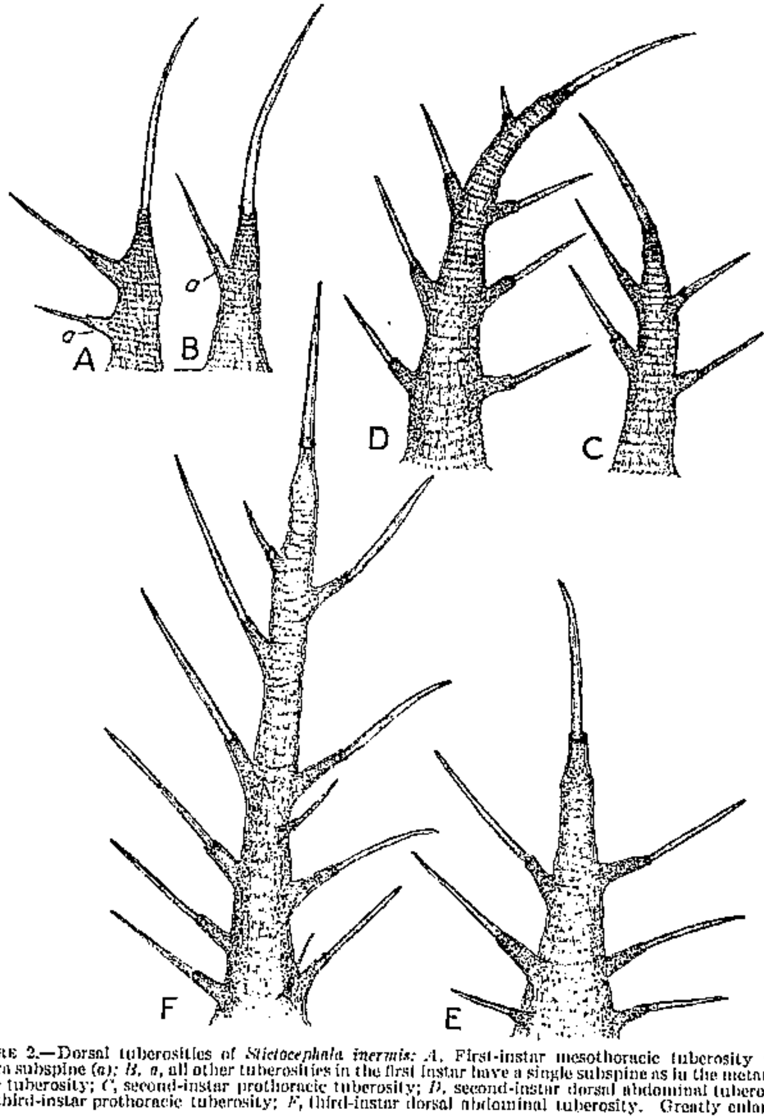


FIGURE 2.—Dorsal tuberosities of *Stictocephala inermis*: *A*, First-instar mesothoracic tuberosity with extra subspine (*a*); *B*, *a*, all other tuberosities in the first instar have a single subspine as in the metathoracic tuberosity; *C*, second-instar prothoracic tuberosity; *D*, second-instar dorsal abdominal tuberosity; *E*, third-instar prothoracic tuberosity; *F*, third-instar dorsal abdominal tuberosity. Greatly enlarged.

Subspines intermingled, numerous, 20 to 25 on each tuberosity (fig. 3, *C*). Body spinose. Wing pads conspicuous, reaching second abdominal segment. Color: Head, part of pronotum, dorsum, venter, and spots along sides faintly testaceous to pale green, otherwise hyaline. Tuberosities faintly suffused.

THE ADULT

Description of adult (pl. 4, *B*; figs. 1, *G*, *H*, and 14, *B*).—Length 7.5 to 9 mm. Head broad, nearly smooth, very finely and faintly punctate, face closely striate between ocelli and eyes. Clypeus and lora short and rounded at the apex. Metopidium perpendicular, dorsal crest high and arcuate, widening above to rounded superhumerals. Tegmina and wings entirely hyaline. Upper part of femora generally black, sometimes this marking absent. Pronotum densely but closely punctate, metopidium convex, median carina distinct but irregular; sides of metopidium meeting before the middle of the body; posterior processes long, slender, gradually acuminate, curving downward, extending beyond abdomen. Segments of abdomen in some cases bordered with black. Last segment of abdomen of female broadly angular. Color: Brilliant green to yellowish.

LIFE HISTORY AND HABITS

In common with the other tree hoppers herein discussed, *Stictocephala inermis* hibernates in the egg stage in the bark of fruit trees (pl. 2, *A*, *B*). These hatch in early spring, the nymphs mature by

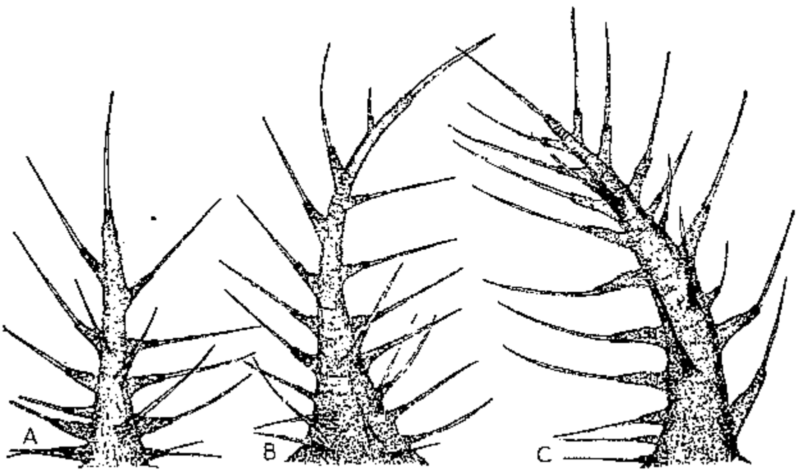


FIGURE 3.—Dorsal tuberosities of *Stictocephala inermis*: *A*, Fourth-instar prothoracic tuberosity; *B*, fourth-instar dorsal abdominal tuberosity; *C*, fifth-instar prothoracic tuberosity. Other tuberosities in the fifth instar turn caudad. Greatly enlarged.

early summer, and the adults lay their eggs during the middle and latter part of the summer. There is one generation a year.

The studies here recorded were carried on at Yakima, Wash., in 1923, 1924, and 1925, with occasional observations in 1926, 1927, and 1928. Many observations were made in the orchards, others in the insectary, some in rearing cages placed over alfalfa plants, and still others in larger cages placed over alfalfa plants and small fruit trees (pl. 3, *A*, *B*)

METHOD OF STUDY

Each season before hatching began, twigs containing eggs were placed with their cut ends in jars of water. Some were allowed to remain in the laboratory, where the temperature ranged from 40° to 75° F.; others were placed in the insectary at out-door temperatures. When the eggs began to hatch in the insectary, it was time to make observations in the orchards. After the first season it was not difficult to foretell at about what time hatching would commence.

When hatching began, representative samples of twigs containing eggs were brought from the orchard to the insectary, where they were kept with their cut ends in bottles or jars of water. The nymphs emerging from these fell upon the paper-covered table, where they were counted hourly throughout the hatching season. Each day individuals were placed in lantern-chimney cages on potted alfalfa plants 2 to 4 inches high. These individuals were examined daily, or often enough to check on the molting process. After the first season the weak, pale alfalfa plants growing under the lantern chimneys were supplemented with freshly gathered succulent alfalfa sprouts. All individuals not used in the studies of molting in the lantern-chimney cages were transferred to the large cages placed over normal alfalfa plants in the insectary yard. General observations were made on these to check against material reared in the insectary and under observation in the orchard.

DATE OF HATCHING

The eggs of *Stictocephala inermis* normally hatch during April and early May (tables 1 and 2; pl. 2, *D*, *E*; fig. 4). In extremely early

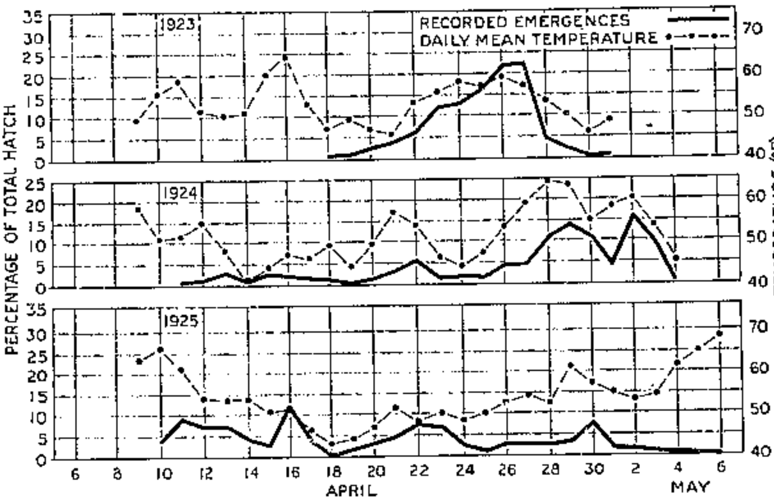


FIGURE 4.—Hatching of eggs of *Stictocephala inermis* in relation to temperature, Yakima, Wash.

seasons, as in 1926, hatching may start as early as the last of March, whereas in extremely late seasons, as in 1927, it may not start until late April. The time of hatching is apparently intimately correlated with bud and blossom development of the fruit trees in the orchards. In the 6 years from 1923 to 1928, inclusive, while these insects were being observed, the hatching invariably commenced when the Winesap blossom buds were in the stage known as "the pink", just preceding the opening of the blossoms. The most favorable weather for hatching appeared to be when the mornings were warm, with a relatively high humidity, preceded by a night of the same character.

The hatching period is much shorter if continuously favorable weather conditions prevail, as in 1923, when the entire hatching period lasted only about 2 weeks (table 1). If interrupted by unfavorable weather conditions, the hatching period may be extended to a month, as occurred in 1925.

TABLE 1.—*Summary of the hatching of eggs of Stictocephala inermis in the insectary, and the relation to temperature, 1923, 1924, and 1925, Yakima, Wash.*

Date	Eggs hatched			Temperature									Precipitation		
	1923	1924	1925	1923			1924			1925			1923	1924	1925
				Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean			
	No.	*No.*	*No.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inch*	*Inch*	*Inch*
Apr. 9	-----	(1)	-----	32	66	49	40	74	58	48	80	63	----	----	----
Apr. 10	-----	-----	[2] 137	41	60	56	39	64	51	53	80	60	----	----	----
Apr. 11	-----	0	373	46	72	58	35	67	52	56	69	61	----	----	T
Apr. 12	-----	15	[3] 310	40	62	52	47	68	55	36	66	54	T	----	----
Apr. 13	-----	36	309	36	64	50	40	60	47	35	68	53	----	----	----
Apr. 14	-----	11	196	35	68	51	34	52	41	44	64	54	----	----	----
Apr. 15	(1)	40	101	45	75	60	35	55	44	48	54	50	----	----	0.36
Apr. 16	-----	29	482	49	78	64	34	62	47	43	63	51	----	----	.15
Apr. 17	-----	20	160	50	57	53	30	59	40	34	58	46	0.08	----	.02
Apr. 18	4	17	0	34	63	47	39	58	49	37	46	43	----	----	.06
Apr. 19	5	1	69	33	60	49	32	57	44	32	58	44	T	----	T
Apr. 20	34	23	125	42	59	47	33	65	49	35	59	47	.08	----	T
Apr. 21	44	44	202	32	59	46	35	75	57	40	64	51	T	----	T
Apr. 22	73	81	321	41	65	53	46	65	54	33	60	48	T	----	T
Apr. 23	154	16	289	43	69	56	37	57	46	37	61	50	----	----	----
Apr. 24	177	26	70	42	73	58	27	59	44	35	56	47	----	----	----
Apr. 25	[4] 215	22	41	38	76	57	26	65	47	41	60	50	----	----	----
Apr. 26	292	65	104	38	77	59	29	71	53	39	64	52	----	----	----
Apr. 27	297	72	[5] 100	47	66	57	38	77	59	40	67	54	----	----	----
Apr. 28	57	167	100	40	65	54	46	76	64	32	70	52	----	----	----
Apr. 29	20	204	154	44	58	50	52	76	63	40	79	61	----	----	----
Apr. 30	0	179	323	32	56	46	41	69	55	44	67	57	----	0.02	----
May 1	3	67	74	35	59	48	39	76	58	45	71	55	T	----	----
May 2	-----	239	52	-----	-----	-----	47	78	60	41	68	53	----	----	----
May 3	-----	150	28	-----	-----	-----	39	66	53	39	68	54	----	----	----
May 4	-----	1	18	-----	-----	-----	33	58	45	47	77	61	----	T	----
May 5	-----	-----	16	-----	-----	-----	-----	-----	-----	50	82	65	T	----	----
May 6	-----	-----	2	-----	-----	-----	-----	-----	-----	52	85	68	----	----	----
Total	1,375	1,531	4,159	-----	-----	-----	-----	-----	-----	-----	-----	-----	.16	.02	.59

[1] Winesap blossom buds in early pink stage.
[2] Hatching already in progress in the field for at least 2 days.
[3] Total for Apr. 13 divided equally with Apr. 12. (Estimate.)
[4] Apples in full bloom.
[5] Total for Apr. 29 divided with Apr. 27 and 28. More is estimated for Apr. 29 owing to higher temperature.

TABLE 2.—*Hatching of eggs of Stictocephala inermis in orchards, Yakima, Wash., 1924 and 1925*

Date eggs examined	Total eggs examined	Condition of eggs						Proportion of viable eggs hatched [1]
		Alive		Hatched		Dead		
1924	*Number*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Percent*
Apr. 18	645	601	93.18	30	4.65	14	2.17	4.75
Apr. 24	462	400	86.58	35	7.58	27	5.84	8.05
Apr. 25	478	396	82.84	53	11.09	29	6.07	11.80
Apr. 26	486	349	71.81	100	20.58	37	7.61	22.27
Apr. 28	507	279	55.03	193	38.07	35	6.90	40.90
Apr. 29	506	249	49.21	189	37.35	68	13.44	43.15
Apr. 30	474	278	58.65	133	28.06	63	13.29	32.36
May 1	426	110	25.82	249	58.45	67	15.73	69.36
May 2	410	51	12.44	268	65.37	91	22.19	84.01
May 3	445	74	16.63	271	60.90	100	22.47	78.55
May 5	830	177	21.33	542	65.30	111	13.37	75.38
May 8	393	18	4.58	331	84.22	44	11.20	94.84
May 10	386	16	4.15	289	74.87	81	20.98	94.75
May 14	389	9	2.31	300	77.12	80	20.57	97.09
Total	6,837	3,007	-----	2,983	-----	847	-----	-----

[1] Based on all eggs not dead.

TABLE 2.—*Hatching of eggs of Stictocephala inermis in orchards, Yakima, Wash., 1924 and 1925*—Continued

Date eggs examined	Total eggs examined	Condition of eggs						Proportion of viable eggs hatched
		Alive		Hatched		Dead		
1925	*Number*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Percent*
Apr. 9	640	575	89.85	10	1.56	55	8.59	17.09
Apr. 10	555	405	72.07	85	15.32	65	11.71	17.35
Apr. 13	620	360	58.07	210	33.87	50	8.06	36.84
Apr. 16	905	435	48.07	405	44.75	65	7.18	48.21
Apr. 17	689	321	46.59	333	48.33	35	5.08	50.92
Apr. 23 [2]	322	59	18.32	217	67.39	46	14.29	78.62
Apr. 24	600	204	34.00	352	58.67	44	7.33	63.31
May 1	381	22	5.77	306	80.32	53	13.91	93.29
May 5	670	25	3.73	585	87.31	60	8.96	95.90
May 10 [3]	645	10	1.55	570	88.37	65	10.08	98.28
Total	6,027	2,416		3,073		538		

[2] Examinations on Apr. 23 were made in 2-year-old trees, whereas others were in twigs from large trees.
[3] The live eggs remaining after about this time were so grown over with new wood that the nymphs would be unable to escape.

FACTORS INFLUENCING THE HATCHING OF EGGS

TIME OF DAY

Practically all hatching of eggs of *Stictocephala inermis* takes place between 7 a.m. and 2 p.m., but usually about 90 percent of it occurs between 8 a.m. and 12 m. (table 3). When the preceding night temperature has been above 50° F., hatching takes place earlier than it otherwise would. Apparently eggs do not hatch at night or in the very early morning, even when the temperature is sufficiently high.

TABLE 3.—*Summary of records of the number of eggs of Stictocephala inermis hatching each hour in the insectary, Yakima, Wash., 1923, 1924, and 1925*

Time; hour ended	Total and proportion of eggs hatching						For the 3 years	
	1923		1924		1925			
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
7 a.m.			9	0.6			9	0.1
8 a.m.	51	3.8	261	17.0	36	0.9	348	5.0
9 a.m.	325	24.3	345	22.5	688	16.5	1,358	19.3
10 a.m.	646	48.4	422	27.6	930	22.4	1,998	28.5
11 a.m.	177	13.3	301	19.7	1,427	34.3	1,905	27.1
12 m.	100	7.5	149	9.7	751	18.0	1,000	14.2
1 p.m.	36	2.7	44	2.9	243	5.8	323	4.6
2 p.m.					70	1.7	70	1.0
3 p.m.					14	.4	14	.2
Total	1,335	100.0	1,531	100.0	4,159	100.0	7,025	100.0

TEMPERATURE

Few eggs hatch on days when the mean temperature is below 45° F. Since nearly all of the eggs hatch during the forenoon between the hours of 8 and 12, the temperature during that period is an important factor. The writer has determined that 50° F. is the critical temperature below which hatching of the eggs rarely occurs. Of 1,335 eggs hatching in 1923 and 4,159 in 1925, none hatched at a shade temperature below 50°. Of 1,531 hatching in 1924, a few are recorded as having hatched at temperatures ranging from 45° to 49° on April 14 and 15, and a few others at 48° on April 23 and 24. When the minimum temperature of the preceding 24 hours was comparatively high, even though it remained just at 50° during the forenoon, considerable hatching occurred. Even when a minimum of 26° had been reached in the morning, hatching occurred during the forenoon after a few hours of 50° temperature had passed, as on April 24 and 25, 1925.

There also appears to be a critical temperature above which hatching ceases. Only five eggs have been recorded as hatching at temperatures above 75° F., and only 56 eggs out of a total of 7,025 are recorded as hatching at 70° and above.

To summarize, when the morning temperature reaches or exceeds 50° in the shade, hatching will begin and continue until about noon or until a temperature of 70° in the shade is reached, after which it will soon cease for the day.

HUMIDITY

Increased hatching has been noted in orchards on mornings when hygrothermograph records indicated high humidity, as occurs especially following night rains or during the period when the orchards are being irrigated. The daily hatching period has been somewhat prolonged on days of excessively high humidity, especially if the temperature was correspondingly favorable. On the other hand, greatly reduced hatching has been noted on days with considerable wind, even when the most favorable temperatures prevailed.

It appears that a certain degree of humidity is necessary to permit the eggs to hatch. The moisture in the air seems to render more pliable the edges of the egg pouches, allowing the extremely delicate nymphs to break through the eggshells, push themselves past the sharp edges of the bark and beyond the surface, and to free themselves from the hatching membranes. It has often been noted that nymphs attempting to emerge late in the morning are sometimes too dried out to complete emergence and die in the attempt.

SITUATION IN THE ORCHARD

Differences occur in various situations in the orchard in the time when hatching takes place. This means that the entire hatching period is somewhat longer in the field than is the case with single lots of material under observation in the insectary.

The earliest eggs to hatch are those in water sprouts growing from the bases of the trees. These sprouts are close to the ground, where they absorb more of the reflected heat from the soil and also from the trunk of the tree. They are also probably first affected by the earliest flow of sap, which evidently increases the moisture content of the bark, cambium, and wood.

One- and two-year old trees, whose trunks are still new enough to be suitable for egg deposition, are much like water sprouts, and the eggs in them hatch earlier than do eggs in twigs in the larger trees. Examination of twigs from a large tree on April 24, 1924, and again on the 25th showed that about 8 to 12 percent of the eggs had hatched; samples from a 2-year-old tree on April 25 showed over 53 percent of the eggs hatched, while a 1-year-old, smaller tree examined on April 24 showed over 77 percent hatched. The young trees receive the same heat reflection from the soil as do the water sprouts, but lack the additional reflection of heat from the trunk.

Eggs in twigs on the south side of large trees hatch earlier than eggs in the twigs on the north side of the same trees (table 4). On April 24 and 25, 17 and 25 percent, respectively, of the live eggs had hatched in twigs on the south side, while at that time none had hatched in the twigs on the north side. On April 26, the day on which hatching started in the twigs on the north side, over 35 percent had hatched on the south side. After a few days more, however, there appears to be little or no difference between the two sides, the general temperature throughout the tree being apparently sufficient to hatch the eggs on the north side, while those on the south side may possibly be somewhat retarded, in certain instances at least, by excessive temperature in the sunlight on that side.

TABLE 4.—*Comparison of the rate of hatching of eggs of Stictocephala inermis in the basal twigs and the terminal twigs, Yakima, Wash., 1924*

NORTH SIDE OF TREE

Date of examination	In basal twigs [1]					In terminal twigs [1]				
	Total eggs	Live eggs	Hatched eggs	Dead eggs	Proportion of viable eggs hatched [2]	Total eggs	Live eggs	Hatched eggs	Dead eggs	Proportion of viable eggs hatched [2]
	Number	*Number*	*Number*	*Number*	*Percent*	*Number*	*Number*	*Number*	*Number*	*Percent*
Apr. 24	129	127	0	2	0	116	97	0	19	0
Apr. 25	121	120	0	1	0	125	114	0	11	0
Apr. 26	97	77	9	11	10.47	131	120	7	4	5.51
Apr. 28	116	77	37	2	32.46	148	128	3	17	2.29
Apr. 29	137	136	0	1	0	112	77	28	7	26.67
Apr. 30	121	95	14	12	12.84	126	88	28	10	24.14
May 1	109	71	35	3	33.02	100	13	59	28	81.94
May 2	102	13	73	16	84.88	112	5	70	37	93.33
May 3	122	17	68	37	80.00	101	33	53	15	61.63
May 5	209	62	117	30	65.36	208	37	150	10	57.47
May 8	105	0	86	19	100.00	95	6	80	9	93.02
May 10	87	5	44	38	89.80	91	0	71	20	100.00
May 14	101	2	87	12	97.75	99	2	65	32	97.01
Total	1,556	802	570	184	....	1,562	720	614	228	....

SOUTH SIDE OF TREE

Date of examination	Total eggs	Live eggs	Hatched eggs	Dead eggs	Proportion of viable eggs hatched	Total eggs	Live eggs	Hatched eggs	Dead eggs	Proportion of viable eggs hatched
Apr. 24	88	49	35	4	41.67	129	127	0	2	0
Apr. 25	111	47	53	11	53.00	121	115	0	6	0
Apr. 26	119	26	76	17	74.51	139	126	8	5	5.97
Apr. 28	131	16	107	8	86.99	112	58	46	8	44.23
Apr. 29	142	24	93	25	79.49	115	12	68	35	85.00
Apr. 30	122	42	51	29	54.84	105	53	40	12	43.01
May 1	111	3	97	11	97.00	106	23	58	25	71.60
May 2	98	9	69	20	88.46	98	24	56	18	70.00
May 3	127	5	95	27	95.00	95	19	55	21	74.32
May 5	207	49	118	40	70.66	208	29	157	22	84.41
May 8	101	0	95	6	100.00	92	12	70	10	85.37
May 10	104	1	90	13	98.90	104	10	84	10	89.36
May 14	93	2	76	15	97.44	96	3	72	21	96.00
Total	1,554	273	1,055	226	....	1,520	611	714	195	....

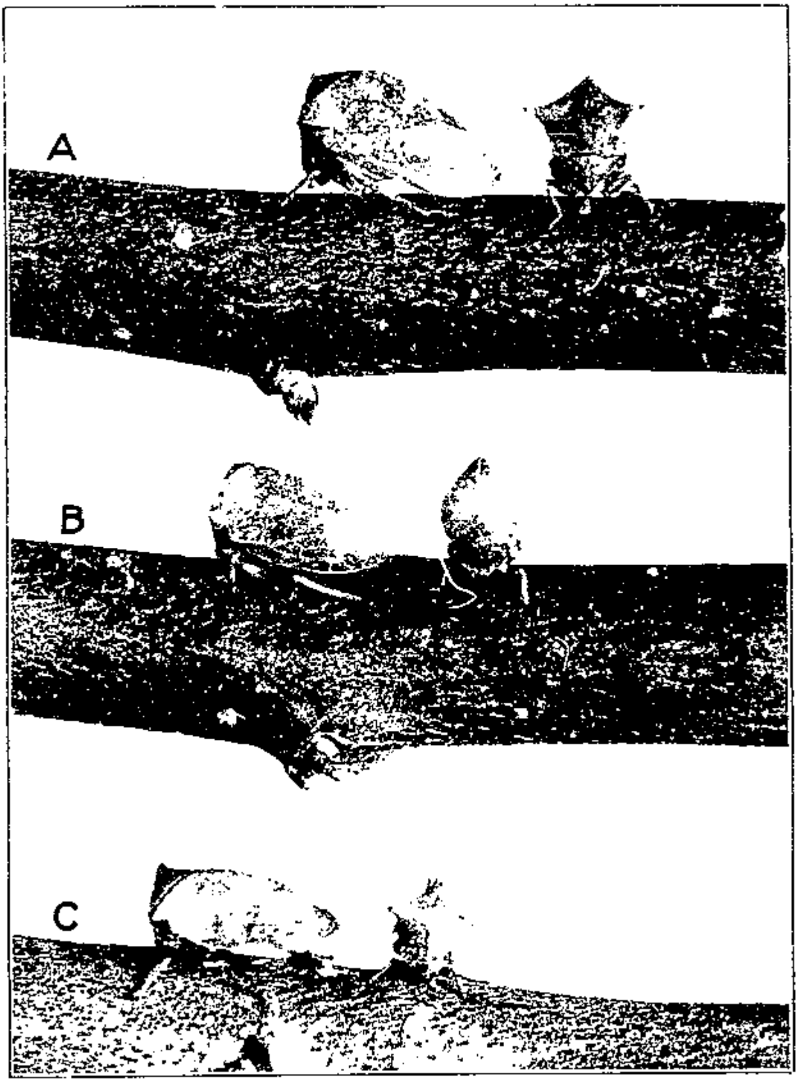
[1] Basal twig samples were from the first few inches next to juncture with larger limbs; terminal samples were from the last few inches in newest wood.
[2] Based on all eggs not dead.

MORTALITY OF EGGS

From time to time varying numbers of the eggs of *Stictocephala inermis* under observation have been found dead. The actual mortality in samples brought for examination has been found as high as 22.5 percent, and a number of samples, totaling 3,252 eggs, showed

TREEHOPPER REARING CAGES.

A, Small cages placed over alfalfa plants in the field. B, Larger cages enclosing young fruit trees.



A, The buffalo treehopper (*Ceresa bubalus*); B, the green clover treehopper (*Stictocephala inermis*); C, the basal, or dark-colored, treehopper (*C. basalis*). All × 3.

an average of 11.7 percent dead. The highest percentage of dead eggs was found in the ends of the pouches where the eggs are excessively crowded by the growing and swelling bark and wood. A higher percentage of dead eggs was generally found at the close of the hatching period than at earlier dates. No difference in mortality appeared among eggs taken from various portions of the tree. Examinations of eggs in twigs which had been held for long periods in the insectary with their basal ends in water showed percentages of mortality only slightly in excess of those observed in the orchard at the end of the hatching period.

FIGURE 5.—Embryo of *Stictocephala inermis* removed from chorion, showing development 2 days before hatching. ×30.

A few of the living eggs are grown over by new wood tissue in early spring before hatching. In such cases the nymphs are unable to escape, and so perish.

MECHANICS OF HATCHING

The embryonic development within the egg apparently takes place chiefly in the early spring shortly before hatching occurs. About 2 days before the eggs are ready to hatch the embryo has the appearance shown in figure 5. The hatching process is shown in figure 6 and is, briefly, as follows:

The embryo nymph enclosed in the embryonic cuticula, often referred to as the "hatching membrane", breaks through the eggshell and forces itself partly out of the egg pouch. The insect then breaks through the hatching membrane and by means of pulsations within the body and a backward and forward as well as sidewise movement works itself free of the membrane. In this process the insect is aided by the tuberosities which are present on the first-instar nymph. Observations of 15 individuals in the insectary showed that the total time required for emergence from the egg ranged from 7 to 16 minutes, with an average of about 13 minutes. As soon as the young

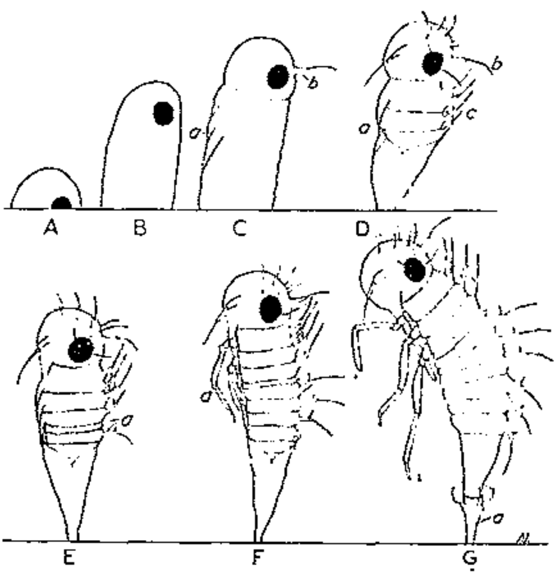


FIGURE 6.—Manner of hatching of tree-hopper nymph: *A*, First appearance of nymph above surface of bark; *B*, 2 minutes later; *C*, 2 to 5 minutes after first appearance, *a*, legs inside hatching membrane, *b*, head tuberosity; *D*, about 2 minutes after stage *C*, *a*, legs, *b*, head tuberosity, *c*, dorsal thoracic tuberosities; *E*, a few seconds after stage *D*, showing first two abdominal segments, *a*; *F*, a few seconds later, showing fifth abdominal segment and legs (*a*) pulling free from shriveled hatching membrane; *G*, a few seconds later, showing the nymph entirely free except for the anal segment, which is still attached inside the hatching membrane *a*. ×30.

nymph can get a foothold it pulls the remaining abdominal tuberosities loose. After freeing itself the nymph takes a few steps and then usually remains quiet for several minutes.

When considerable numbers of young have hatched, the empty, white, shriveled hatching membranes stand out conspicuously against the dark background of the twig (pl. 2, *D*) with their lower ends attached down within the egg pouch. These remain for some time, and by the end of the hatching period they give a badly infested twig a whitish, fuzzy appearance.

At times thousands of nymphs appear at approximately the same time and fall to the ground with each stir of air like miniature gusts of snow. The presence of hundreds of the whitish nymphs protruding at one time from the ragged bark of badly infested twigs (pl. 2, *E*)—sometimes two or more at the same time from a single egg pouch—is an interesting sight and was evidently responsible for Lovett's belief (*18*) that 90 percent of the eggs hatch within a few hours. Actually, of course, the percentage hatching on any one day is much less than that figure.

HABITS OF NYMPHS

As previously indicated, the nymphs normally feed on certain herbaceous plants; in the Northwest they are found chiefly on alfalfa. The foliage of fruit trees is evidently unsuitable as food for the young nymphs, for practically all of them drop from the tree very shortly after hatching, and the writer has been unable to rear nymphs on apple foliage in the insectary. If there are strong air currents when the nymphs are hatching and dropping to the ground, they may be blown some little distance from the tree. Those which happen to reach suitable plants establish themselves and feed on such plants until becoming adults, which requires from 50 to 90 days. In the earlier stages the nymphs prefer the shaded, humid conditions prevailing at the base of the alfalfa crowns. As they develop to the fourth and fifth stages they are not so partial in this respect, and may be found several inches up on the alfalfa stems.

Feeding nymphs remain at the same place for hours at a time and do not appear to move about very much. In the later stages the nymphs are always found with their heads turned toward the base of the stems. It has been suggested that this habit is probably for the purpose of obtaining a protective resemblance, although when the insect is feeding upon alfalfa it is difficult to see that any protection is afforded by this position.

The feeding of the nymphs causes moderate injury, similar to that shown in plate 2, *C*. In alfalfa in orchards in the Northwest, however, this has not been found extensive enough to be of serious importance.

MOLTING

The nymphs pass through five instars before reaching maturity. The molts are very much alike and are about as follows: The nymph fastens itself with its feet to the plant upon which it has been feeding and remains quiet for a number of hours. The outer integument loosens at a number of places over the body and separates from the new skin formed beneath. The old integument breaks at the back of the head and then splits along the median dorsal line, as well as over the mouth parts. The legs, after being pulled free, are waved about until they catch hold of the leaf or stem, when they assist in pulling the tip of the abdomen free from the integument. Two nymphs were timed for the length of the molting process. One required 15 and the other 17 minutes. After freeing themselves they remained quiet for 23 and 45 minutes, respectively. The old integument is left attached to the undersides of leaves of alfalfa or sweetclover until brushed or knocked off.

NYMPHAL DEVELOPMENT

Detailed observations as to the duration of the nymphal instars were made in 1924. The insects were reared in lantern-globe cages on thrifty alfalfa plants, supplemented with freshly cut alfalfa stems and leaves taken from as near the base of alfalfa plants as possible.

The record of the lengths of the nymphal instars of *Stictocephala inermis*, as observed in rearing 57 individuals in the insectary in 1924, are given in summary form in table 5.

TABLE 5.—*Length of the nymphal instars of 57 individuals of Stictocephala inermis hatched at daily intervals from Apr. 12 to May 12, 1924, Yakima, Wash.*

Item	First instar	Second instar	Third instar	Fourth instar	Fifth instar	Total nymphal period
EGGS HATCHED FROM APR. 12 TO 20						
	Days	*Days*	*Days*	*Days*	*Days*	*Days*
Maximum	27	12	10	17	31	91
Minimum	21	7	8	13	22	75
Average	23.3	9.1	8.9	14.6	26.1	82.0
EGGS HATCHED FROM APR. 21 TO 30						
Maximum	22	10	10	19	29	77
Minimum	12	7	7	10	22	65
Average	16.7	8.0	8.3	12.9	24.6	70.5
EGGS HATCHED FROM MAY 1 TO 12						
Maximum	15	9	9	12	24	62
Minimum	7	7	7	7	15	50
Average	10.8	7.6	8.0	9.9	19.0	55.2
Maximum for all	27	12	10	19	31	91
Minimum for all	7	7	7	7	15	50
Average for all	16.4	8.2	8.4	12.3	22.0	68.1

As will be noted in table 5, the earliest-hatched nymphs require a much longer time to reach maturity than late-hatched nymphs. In this table the hatching records obtained for 1924 are divided arbitrarily into three groups, according to the period in which they hatched. There is a marked tendency for the late-hatched nymphs to catch up in their development with those which hatched earlier in the season. The nymphs in this series of observations hatched over a period of 31 days from April 12, but all became mature between June 26 and July 13. Many of the latest to hatch were among the earliest to reach maturity, the last one to reach maturity having emerged from the egg April 13, whereas the first one to mature was hatched on May 7.

In 1924, to determine the difference between sunlight and shade as factors in development, newly hatched nymphs were caged on an alfalfa plant growing in the shade, where no direct sunlight penetrated at any time, and others were caged on another alfalfa plant out in the open yard, where they received as much sunlight as was possible. On July 5 there were 9 adults in the cage in the sunlight, whereas none appeared in the shaded cage until July 16, when 12 adults emerged, all of which were males. Apparently it required at least 11 days longer for development in the shaded cage than in the one in the sunlight. Whether the shade had anything to do with producing all males is not known, neither is it known whether males require a longer period for their development.

ADULT STAGE

A technical description of the adult of *Stictocephala inermis* is given on page 6. It is readily distinguished from its close associate *Ceresa bubalus* (pl. 4, *A*), the true buffalo tree hopper, by the rounded humeral angles and the absence of humeral horns (plate 4, *B*). *S. inermis* is intermediate in size between *C. bubalus* and *C. basalis*. It is readily distinguished from *basalis*, being greenish throughout, whereas *basalis* is dark on the under side of the body and usually has dark markings on the legs.

Records of the length of adult life of individuals confined in the insectary are shown in table 6. Under normal orchard conditions the average length of life is probably about 2 months, and adults are found in the orchard from late June until late September.

TABLE 6.—*Longevity of adults of Stictocephala inermis in confinement, Yakima, Wash., 1924*

Number of individuals	Minimum length of life of group	Number of individuals	Minimum length of life of group	Number of individuals	Minimum length of life of group
	Days		*Days*		*Days*
1	67	10	50	29	40
3	58	13	49	39	38
5	54	20	44	41	37

MATING

According to Funkhouser (*12*), who described the process, mating begins almost immediately after the sexes reach maturity. Mating lasted from 5 minutes to 1 hour in different species, and he observed no forms in flight during mating.

In spite of repeated observations at all hours of day and night, the writer has never observed the mating process.

OVIPOSITION

There seems to be a preoviposition period of about 25 days. Few eggs are ever found before the middle of July, and few seem to be laid after the first of September. There is therefore an egg-laying period of possibly 60 days, and a period of about 35 or 40 days during which most of the eggs are deposited.

Oviposition occurs chiefly between the hours of 10 a.m. and 5:30 p.m., though a few eggs may be deposited later during the long, warm, sunny evenings of August. Numerous observations failed to indicate any ovipositions earlier than 10 a.m. Funkhouser (*12*), at Ithaca, N.Y., reported most oviposition as taking place during the afternoon, and this is probably true of *S. inermis* and allied species in the Yakima Valley. Wildermuth (*30*) states that *S. festina* deposits its eggs at night. This may be on account of the higher temperature prevailing throughout most of the regions where *festina* is known to occur.

The eggs are laid in groups of 1 to 11 in pouches in the bark and wood (pl. 2, *A* and *B*). They are placed chiefly in the youngest of the previous season's wood, although a few may be laid in the most mature of the current season's growth.

On large trees, more eggs are deposited on the south than on the north side. On twigs extending in a more or less horizontal direction, nearly all eggs are deposited on the upper sides. Young trees and sprouts standing more or less vertically have more eggs on the south side. In young trees, most of the eggs are deposited within 2 feet of the ground. In older trees, low-hanging twigs drooping into the alfalfa are especially favorable places for deposition. Very few eggs are found more than 6 or 7 feet above the ground, although sometimes an occasional egg pouch is found well up in the large trees.

The eggs are inserted through the bark and into the outer wood (fig. 7, *F*, *G*, *H*, and *I*; pl. 2, *A* and *B*), the inner ends extending slightly into the outer surface of the wood, their outer ends at or slightly past the surface of the inner scar; so the tips of the eggs are often visible when the loose bark flap is lifted slightly, or is removed by the elements, as often happens after several months of exposure. The exposure of egg tips is of importance in the matter of control of the insect. In badly infested twigs the egg pouches or scars are very numerous and often cut into each other, in which case some of the eggs exposed by the later cuts are killed.

MANNER OF DEPOSITION OF EGGS

In making the slit for the eggs, the female raises her body as high as possible, unsheathes her ovipositor with its sawlike posterior edge, and slowly and methodically pushes it perpendicularly into the bark. In this perpendicular thrust the ovipositor often bends a number of times during a single insertion, owing, no doubt, to the resistance of the bark and wood. By slow up-and-down sawing movements the ovipositor is gradually worked backward until it is about in line with the body, when it is withdrawn. After this slit has been made a couple of supplementary slits are made at the side of the main incision. These are usually not so deep as the main slit and run in different directions from the original (fig. 7, *D*).

After making the supplementary slits the female again inserts her ovipositor into the egg slit from which it was last withdrawn, resumes the initial position, and slowly deposits an egg. After about 45 seconds, or less, the ovipositor is partly withdrawn and reinserted in advance of the egg just laid. In reinserting the ovipositor the tip is thrust forward of perpendicular at a considerable angle. The time required for the whole operation of inserting each egg ranges from 35 to 70 seconds, but usually averages between 45 and 60 seconds. Sometimes it is necessary for the ovipositor to be withdrawn and

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reinserted a number of times before deposition is accomplished. It requires the longest time to deposit the eggs at the ends of the slits, and considerable manipulation is often necessary to accomplish this. When the full number of eggs for the pouch has been deposited the

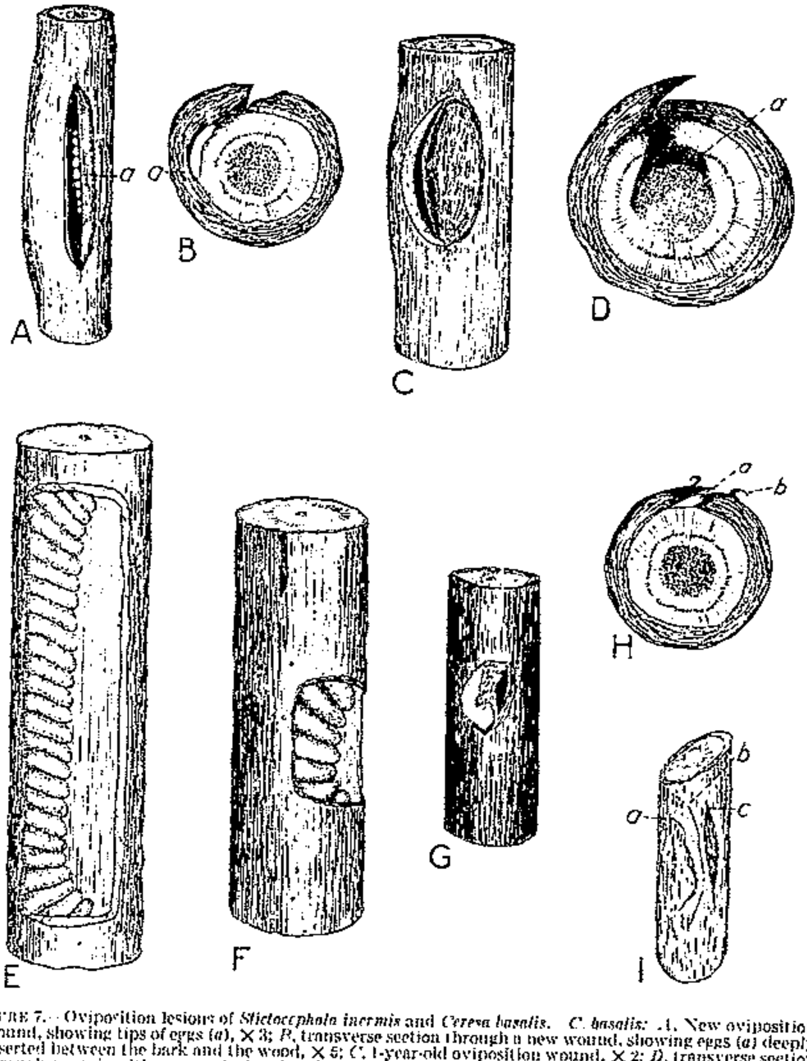

FIGURE 7.—Oviposition lesions of *Stictocephala inermis* and *Ceresa basalis*. *C. basalis*: *A*, New oviposition wound, showing tips of eggs (*a*), × 3; *B*, transverse section through a new wound, showing eggs (*a*) deeply inserted between the bark and the wood, × 5; *C*, 1-year-old oviposition wound, × 2; *D*, transverse section through an oviposition wound, showing decay (*a*) penetrating through to the heartwood, × 7; *E*, section of twig with bark removed, showing the position of *basalis* eggs in the egg pouch, × 4. *S. inermis*: *F*, Apple twig with bark removed to show position of *inermis* eggs in the egg pouch, × 4; *G*, oviposition scar of *inermis*, × 2; *H*, transverse section through oviposition pouch in an apple twig, showing (*a*) the shallow position of the egg, and (*b*) the curled edges of the outer bark characteristic of this species, × 5; *I*, oviposition scar (*c*) and supplementary incisions (*a* and *b*) which cause the curling of the outer bark, × 4.

female withdraws her ovipositor, resheathes it, walks away, and rests.

The supplementary slits kill the outer bark on either side of the egg slit, causing the free edges to curl away from the cut (pl. 1), and resulting in the roughened, shaggy appearance characteristic of the bark of infested twigs. Although the purpose of the supplementary slits is unknown, the killing of the outer bark around the egg pouch prevents the eggs from being grown over by the bark and wood, which might prevent them from hatching the following year. *Ceresa bubalus* cuts two longitudinal slits, between which the wood does not grow, thus protecting her eggs. *C. basalis* cuts a deep, long, longitudinal slit, which usually opens and widens instead of growing over.

The number of eggs in each slit or pouch ranges from 1 to 11 (table 7). The average number of eggs in 3,765 pouches, dissected under the microscope in 1923, 1924, and 1925, was 5.6.

TABLE 7.—*Number of eggs per pouch laid by Stictocephala inermis, Yakima, Wash., 1923, 1924, 1925*

Year	Pouches containing the number of eggs indicated											Total
	1	2	3	4	5	6	7	8	9	10	11	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1923	6	19	69	203	650	727	366	114	25	10	1	2,190
1924	3	26	70	185	318	262	118	28	12	1	0	1,023
1925	0	10	25	55	150	185	85	30	6	0	0	546
Total	9	55	164	443	1,124	1,174	569	172	43	11	1	3,765

The number of egg pouches made by the *inermis* female was not determined because of difficulty in approximating normal environmental conditions. In rearing cages placed over young fruit trees into which were introduced large numbers of females, the highest average number of egg pouches in any one cage was 8.6 per female, with an average of 47 eggs for each female. Hodgkiss (*17*) reports one female as depositing 252 eggs in 59 scars and another individual as placing 212 eggs in 39 scars. It is probable that not less than 200 eggs would represent a fair average per individual for conditions in the Yakima Valley. Certainly few females are seen ovipositing compared with the thousands of eggs deposited.

CERESA BASALIS WALK.

HISTORY AND DISTRIBUTION

Another membracid more or less commonly associated with *Stictocephala inermis* is *Ceresa basalis*. This species is at present less numerous than *S. inermis*, and the evidences of its presence are less abundant. In some respects, however, it is more injurious on account of the nature of its injury, which is more pronounced than that of any of the other species with which the writer is acquainted.

The first reference to *C. basalis* as occurring in the Pacific Northwest was by Wilson (*31*) in Oregon in 1915. Downes (*5*) listed it as occurring in British Columbia in 1917 and 1918 and reported it as the commonest membracid found there. The writer (*32, 33*) discussed it as common in Washington and elsewhere in the Pacific Northwest in 1924 and later. Essig (*6*) mentions it as occurring also in California, Utah, and New Mexico, and in eastern States. Funkhouser (*13*) reports it from the following States and Canadian Provinces: New Hampshire, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Kentucky, Ohio, Indiana, Illinois, Kansas, Colorado, Utah, Idaho, New Mexico, California, Oregon, Washington, Nova Scotia, Quebec, Ontario, Manitoba, Saskatchewan, and British Columbia. It is therefore probably distributed throughout the southern Provinces of Canada and throughout the United States except in the extreme Southeastern States.

SYNONYMY AND COMMON NAME

This species was first described by Walker (*29, p. 527*), in 1851, from specimens from Nova Scotia. In 1889 Provancher (*22, p. 235*) redescribed it as *brevicornis* and also as *semicrema*. Osborn, in 1893, as reported by Nutting (*20, p. 290*), designated it *melanogaster*. Goding (*14, p. 406*), in 1894, classified it as *basalis* and also designated it as a new species, *turbida*. Buckton, in 1903 (*4, p. 174*), described it as *semibrunnea* and placed it in the genus *Stictocephala* of Stål. After Van Duzee's discussion of it in 1908 (*28, p. 114*), under its original designation of *Ceresa basalis*, all subsequent references have retained this name.

The most important references to this species are by Funkhouser (*13*), in 1927, and by the writer (*32*) in 1924 and (*33*) in 1930.

This species has been called by the common names "western tree hopper" by the writer (*32, p. 97*); the "basal tree hopper," by Essig (*6, p. 204*); and the "dark-colored tree hopper", by the writer (*33, p. 2*).

The more important synonymy is as follows:

Ceresa basalis Walker, 1851 (*29, p. 527*)
Ceresa brevicornis Provancher, 1889 (*22, p. 235*)
Ceresa semicrema Provancher, 1889 (*22, p. 235*)
Ceresa melanogaster Osborn, 1893 (*20, p. 290*)
Ceresa turbida Goding, 1894 (*14, p. 406*)
Stictocephala semibrunnea Buckton, 1903 (*4, p. 174*)
Ceresa basalis Van Duzee, 1908 (*28, p. 114*)

CHARACTER AND IMPORTANCE OF INJURY

The oviposition scars of *C. basalis* consist of long, deeply cut, longitudinal slits, which penetrate through the bark and into the wood (fig. 7, *A*, *C*; pl. 5, *B*). Although the scars appear slight when first made, the edges of the slit separate as the twig grows until a clear-cut and very pronounced incision results. The widening of the scar often continues through succeeding seasons, until the wood underneath the wound is exposed (pl. 5, *A*, *a*). These wounds often become infested by the woolly apple aphid, *Eriosoma lanigerum* Hausm., which interferes seriously with their healing. In some instances decays enter through these wounds and penetrate into the wood (fig. 7, *D*).

While less numerous than the scars made by *S. inermis*, the wounds caused by this membracid are much more conspicuous and more readily noticed. The wounds are deeper, and the actual damage to the tree or twig is much greater. These wounds often cause the death of the terminal growth of the twigs (pl. 5, *C* and *D*). Usually a half dozen scars in the terminal 6 inches of the twig are sufficient to kill it.

As in the case of injury by *Stictocephala inermis*, nursery trees and young orchard trees are the most seriously affected. Egg scars of

TREEHOPPER INJURIES TO TWIGS

A, Old oviposition scars of *Ceresa basalis* and *C. bubalus*; *a*, wounds of *basalis* widened to such an extent as to expose the wood underneath, *b*, old oviposition scars of *C. bubalus*. B, Oviposition scars of *C. basalis* in *a*, pear, *b*, willow, *c*, apple, *d*, locust, and *e*, prune. × 2/3. C, Two-year-old apple tree showing serious infestation by both *Stictocephala inermis* and *C. basalis*, the death of the twigs beyond the leaf clusters was caused by the scars of *C. basalis*. D, Terminal apple twig killed by *C. basalis*; the twig beyond the leaf cluster is dead as oviposition slits were made in the twig to within 1 inch of the terminal bud.

A, Apple twig showing scars of *Ceresa bubalus* at *a*, of *C. basalis* at *b* and *d*, and of *Stictocephala inermis* at *c*; *a* and *d* show also the presence of the woolly apple aphid; the twig at the right is the terminal of the one on the left and shows less infestation. B, Oviposition scars of *C. bubalus* on elm. C, Two groups of *C. basalis* eggs with bark and wood removed showing the curved line made by the ends of the eggs. The group at the left was taken during the hatching period and shows unhatched eggs at the ends. ×3 this species have been found in apple, peach, pear, willow, locust, and prune trees. Fortunately, *C. basalis* is comparatively scarce at the present time, or very serious injury would result to fruit trees in the Northwest.

FOOD PLANTS

The only known food plants of this species in the Pacific Northwest are alfalfa and sweetclover. It has been reported by Downes (*5*) on goldenrod, and other herbaceous plants, but whether for feeding or oviposition is not stated. Funkhouser (*12*) reports it on rose, probably being there for oviposition purposes only.

DESCRIPTION OF INSTARS

The egg and the five nymphal instars of *Ceresa basalis* are very similar to those of *Stictocephala inermis*, already described. The main apparent difference between the nymphal instars of the two species is in the somewhat darker spots on the integument of *basalis*. Measurements of the several instars (fig. 8) are as follows: First instar 1.65 to 1.85 mm, second instar 2.35 to 2.75 mm, third instar 3.25 to 4.0 mm, fourth instar 5.0 to 5.75 mm, fifth instar 6.0 to 6.75 mm.

Detailed examinations of the tuberosities of the five instars of *C. basalis* show the same number of tuberosity spines in the first instar (fig. 9, *A*) as in *S. inermis*, 7 to 10 tuberosity spines in the second instar (fig. 9, *B*), 11 to 20 or more in the third instar (fig. 10), 13 to 26 or more in the fourth instar (fig. 11), and 25 to 33 or more in the fifth instar (fig. 12). The tuberosities are shorter, heavier, and comparatively broader at the base than those of *S. inermis* (fig. 13, *A* and *B*). There are more subspines on the tuberosities than with *S. inermis*, and these are shorter and more slender. In the second instar short subspines appear on the base of the tuberosities. These become more numerous in succeeding instars until there are at least 7 or 8 of them on each tuberosity in the fourth and fifth instars.

DESCRIPTION OF ADULT

Head broader than long, roughly punctured, not pubescent; eyes prominent, extending as far laterally as humeral angles; ocelli distinct, reddish; pronotum deeply punctate, very hairy, humeral angles prominent, superhumeral horns short, obtuse, horizontal; dorsal crest convex; posterior process slender, dark, slightly decurved at tip. Under surface of body black below and segments dark bordered. Under parts of head and large part of femora black or dark brown. Length 7.5 mm. (See pl. 4, *C*; figs. 8, *G*, *H*, and 14, *D*.)

LIFE HISTORY AND HABITS

The observations on the life history and habits of this species were made, for the most part, coincident with those on *Stictocephala inermis* and other species, but certain experiments were conducted on this species alone. Much of the discussion for *S. inermis* serves equally well for *Ceresa basalis*.

HIBERNATION AND HATCHING

The eggs of *C. basalis* (fig. 7, *B*, *E*) are deposited in August and September, and the egg is the only stage in which the insect survives the winter. Although the earliest eggs of *Stictocephala inermis* are deposited in the middle or latter part of July, it is probable that no *basalis* eggs are laid until the 1st of August.

As the eggs are deposited much deeper in the wood than are those of *S. inermis* (fig. 7, *B*, *a*, compare with *H*, *a*), they seem to require more accumulated temperature to incubate them, and consequently they do not begin hatching until 3 weeks or more after those of *S. inermis*, or at about the time the last of these have hatched.

Records of the hatching of eggs brought into the insectary in 1924 and in 1925 are given in table 8. Observations made in the field as

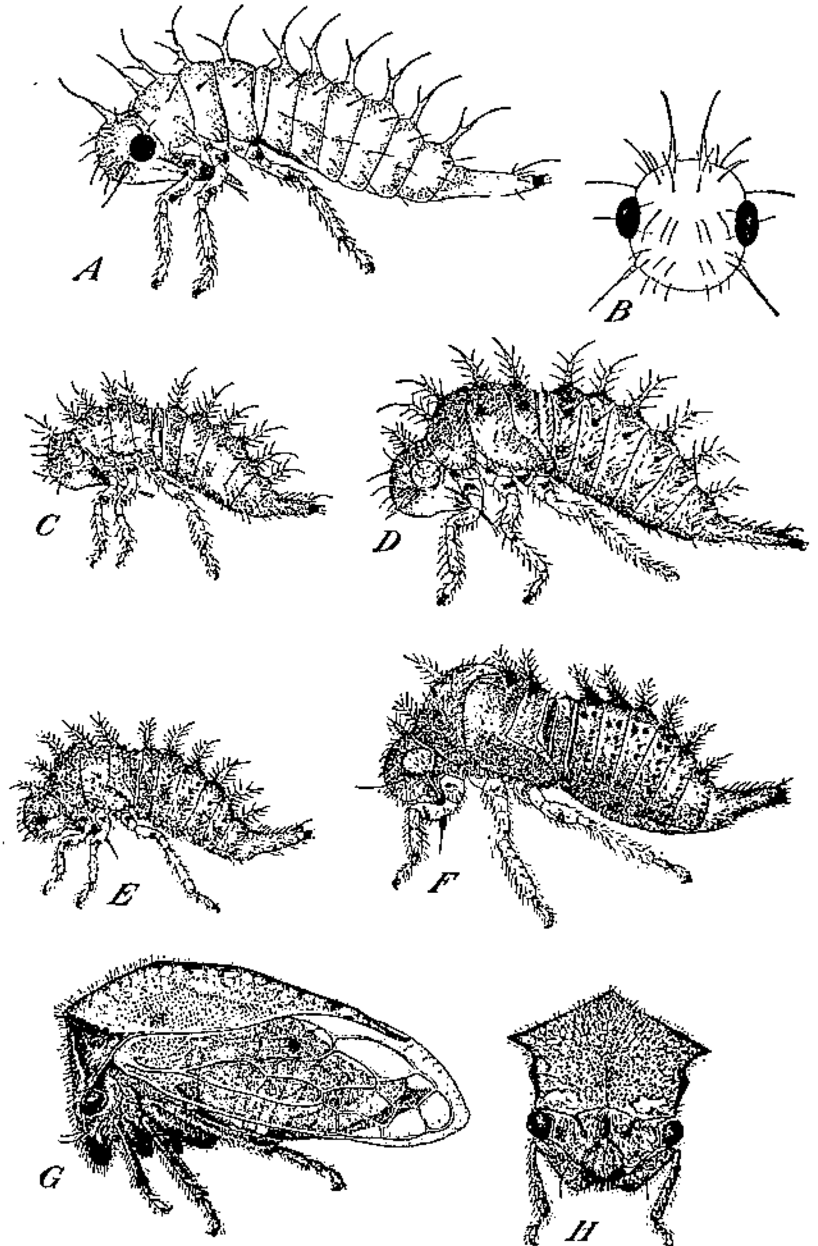

FIGURE 8.—Successive stages in the development of *Ceresa basalis*: *A*, First instar nymph, side view, ×35; *B*, first instar, front view of head, ×45; *C*, second instar, ×15; *D*, third instar, ×15; *E*, fourth instar, ×7; *F*, fifth instar, ×8; *G*, adult, side view, ×7; *H*, adult, front view, ×7.

to the progress of hatching in 1924 are shown in table 9. In 1924 and 1925 the first hatching in the orchard was observed on April 30, and the last on May 13 in 1924 and May 17 in 1925.

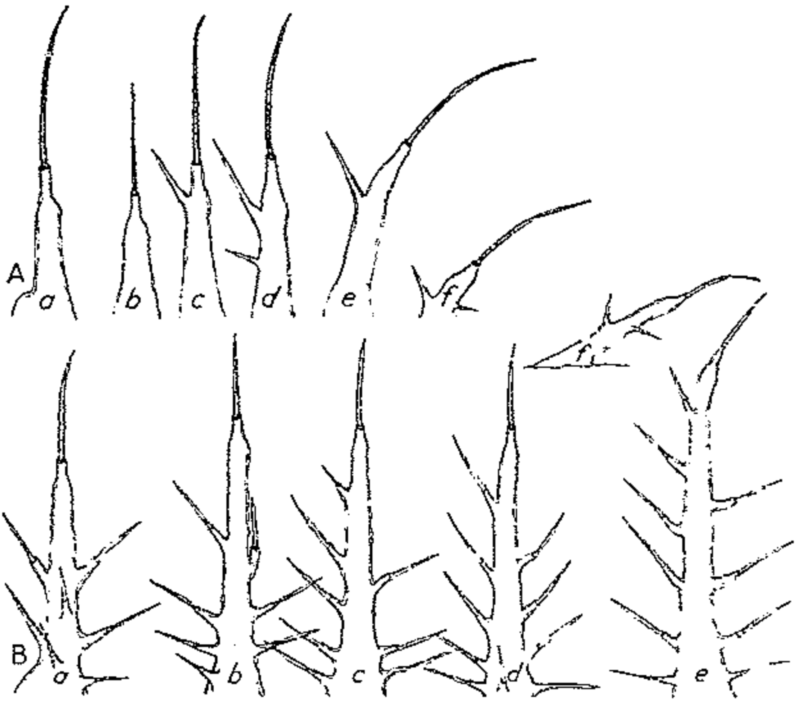

FIGURE 9.—Dorsal tuberosities on nymphs of *Ceresa basalis*: *A*, First instar; *a*, head tuberosity; *b*, first prothoracic tuberosity; *c*, second prothoracic; *d*, mesothoracic; *e*, abdominal; *f*, anal. *B*, Second instar (the same designations).

TABLE 8.—*Summary of the hatching of eggs of Ceresa basalis in the insectary, and the relation to temperature, 1924 and 1925, Yakima, Wash.*

Date	Eggs hatched		Temperature					
			1924			1925		
	1924	1925	Minimum	Maximum	Mean	Minimum	Maximum	Mean
	Number	*Number*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
May 1	0	0	39	76	58	45	71	55
May 2	0	0	47	78	60	41	68	53
May 3	0	0	39	66	53	39	68	54
May 4	[1] 1	0	33	58	45	47	77	61
May 5	21	14	35	63	51	50	82	65
May 6	72	[1] 5	40	74	56	52	85	68
May 7	73	0	39	72	58	44	48	46
May 8	140	0	47	80	64	43	56	48
May 9	141	6	54	87	71	36	68	54
May 10	123	0	55	90	73	50	73	61
May 11	93	37	57	92	74	48	74	60
May 12	7	40	60	93	78	40	75	62
May 13	0	40	68	92	77	53	78	65
May 14		28				58	84	70
May 15		11				54	84	69
May 16		5				63	82	72
May 17		2				58	70	68
May 18		2				58	68	63
Total	671	190						

[1] Last recorded hatching of *S. inermis* in the insectary.

TABLE 9.—*Hatching of eggs of Ceresa basalis in apple twigs in an orchard, Yakima, Wash., 1934*

Date of observation	Total eggs observed	Condition of eggs						Proportion of viable eggs hatched[1]
		Alive		Hatched		Dead		
	Number	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Percent*
Mar. 22	210	178	84.8	0	0	32	15.2	0
Apr. 1	1,105	958	86.7	0	0	147	13.3	0
Apr. 8	36	27	75.0	0	0	9	25.0	0
May 1	632	485	76.7	0	0	147	23.3	0
May 3	198	147	74.2	33	16.7	18	9.1	18.3
May 8	1,167	602	51.6	212	18.2	353	30.2	26.0
May 9	708	184	26.0	174	24.6	350	49.4	48.6
May 14	1,625	5	.	463	28.5	1,157	71.2	98.9
Total or average	5,681	2,586	45.5	882	15.5	2,213	39.0	61.0

[1] Based on all eggs not dead.

The hatching period for *C. basalis* is very short (10 days or 2 weeks), probably because of the high temperatures occurring at that time.

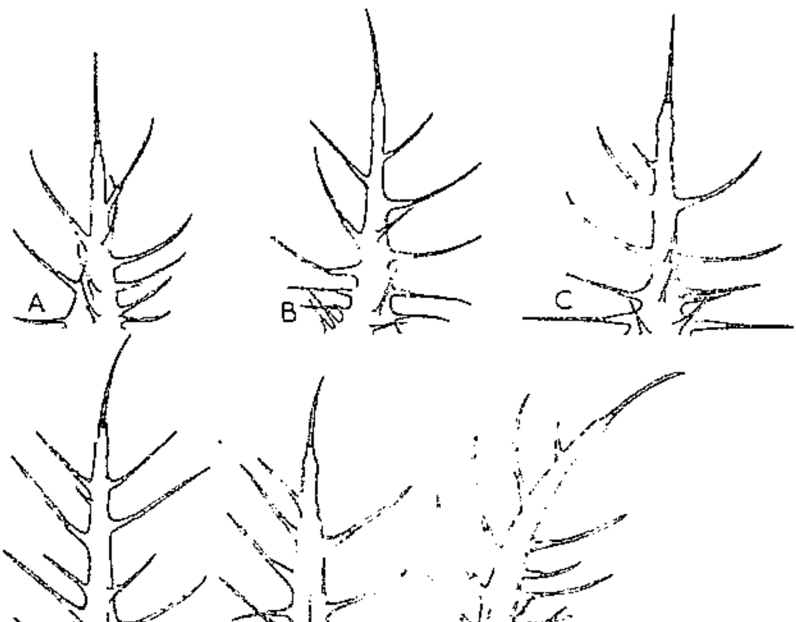

FIGURE 10. Dorsal tuberosities on third-instar nymphs of *Ceresa basalis*: *A*, Head tuberosity; *B*, first prothoracic tuberosity; *C*, second prothoracic; *D*, mesothoracic; *E*, metathoracic; *F*, abdominal; *G*, anal.

The hatching process of *basalis* eggs is as described for the eggs of *inermis*, and the weather conditions conducive to the hatching of one species are apparently favorable for the other, although *basalis* requires a higher degree of temperature or a greater accumulation of day degrees in the spring to start hatching.

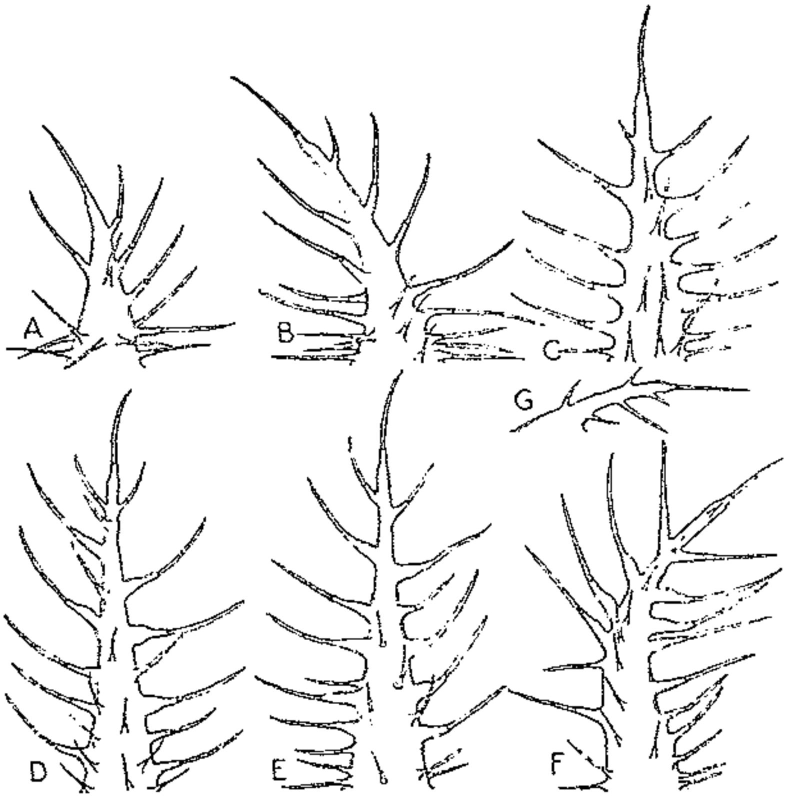

FIGURE 11.—Dorsal tuberosities on fourth-instar nymphs of *Ceresa basalis*. (Designations as in fig. 10.)

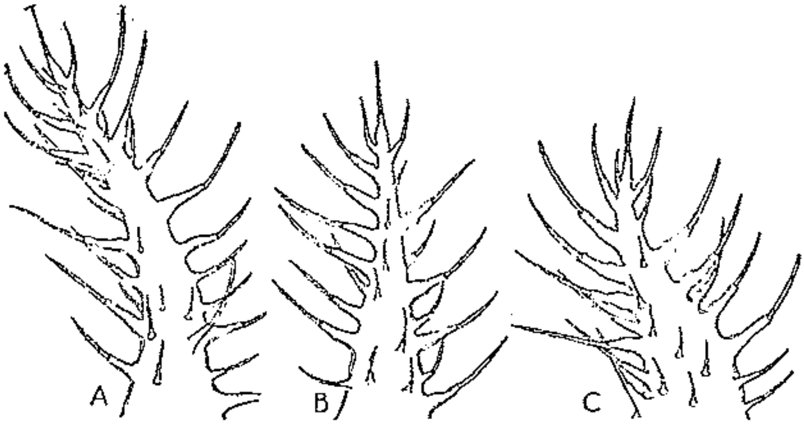

FIGURE 12.—Dorsal tuberosities on fifth-instar nymphs of *Ceresa basalis*: *A*, Mesothoracic tuberosity; *B*, metathoracic tuberosity; *C*, abdominal tuberosity.

MORTALITY OF EGGS

The extremely high mortality of the eggs of this species is worthy of note. As shown in table 10 the mortality is greatest in terminal twigs which have been killed by the presence of egg punctures of this species. Evidently, few of the eggs are able to withstand the shrinking, withering effect of the drying wood. In live wood most of the dead eggs are found at the ends of the egg pouches (pl. 6, *C*), and these have probably been injured by the pressure of the growing wood and bark.

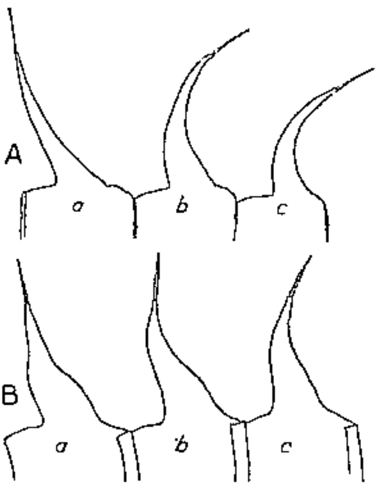

FIGURE 13.—Diagrammatic representation of dorsal tuberosities: *A*, *a*, *b*, and *c*, first, second, and third abdominal tuberosities of *Stictocephala inermis* (long, slender, spinate, curving more or less strongly caudad); *B*, *a*, *b*, *c*, first, second, and third abdominal tuberosities of *Ceresa basalis* (broad, stout, leaning forward, and not curving so strongly caudad as in *Stictocephala inermis*).

Occasionally the eggs are sealed over by the growing bark and wood. An extreme case of this was observed in sprouts taken from a prune tree in which the eggs in 37 egg pouches were mostly alive but were sealed in by overgrowing bark and wood. Examination of these eggs a month after the close of the normal hatching period showed them to be fresh, plump, and seemingly alive, with normally developed embryos showing eyes, abdominal segmentation, and legs.

Since the death of the terminals is usually the direct result of oviposition farther back by this species, the insect is its own worst enemy. This high mortality is an important factor in keeping this insect from becoming a serious economic pest.

TABLE 10.—*Comparison of the mortality of eggs of Ceresa basalis in live parts and dead withered terminals of the same twigs, Yakima, Wash., 1924*

Date of observation	In live parts of twigs		In dead, withered terminals of same twigs		Proportion of eggs dead in—	
	Eggs hatched or alive	Eggs dead	Eggs hatched or alive	Eggs dead	Live twigs	Dead terminals
	Number	*Number*	*Number*	*Number*	*Percent*	*Percent*
Apr. 1	938	85	20	62	8.31	75.61
Apr. 8	24	6	3	3	20.00	50.00
May 1	446	56	39	91	11.16	70.00
May 3	148	1	32	17	.67	34.69
May 8	736	122	78	231	14.22	74.76
May 9	312	99	46	251	24.09	84.51
May 14	433	201	35	958	31.70	96.47
Total	3,037	570	253	1,611		...

HATCHING OF EGGS

As in the case of *Stictocephala inermis,* the eggs of *Ceresa basalis* hatch during the forenoon, although they have a tendency to hatch

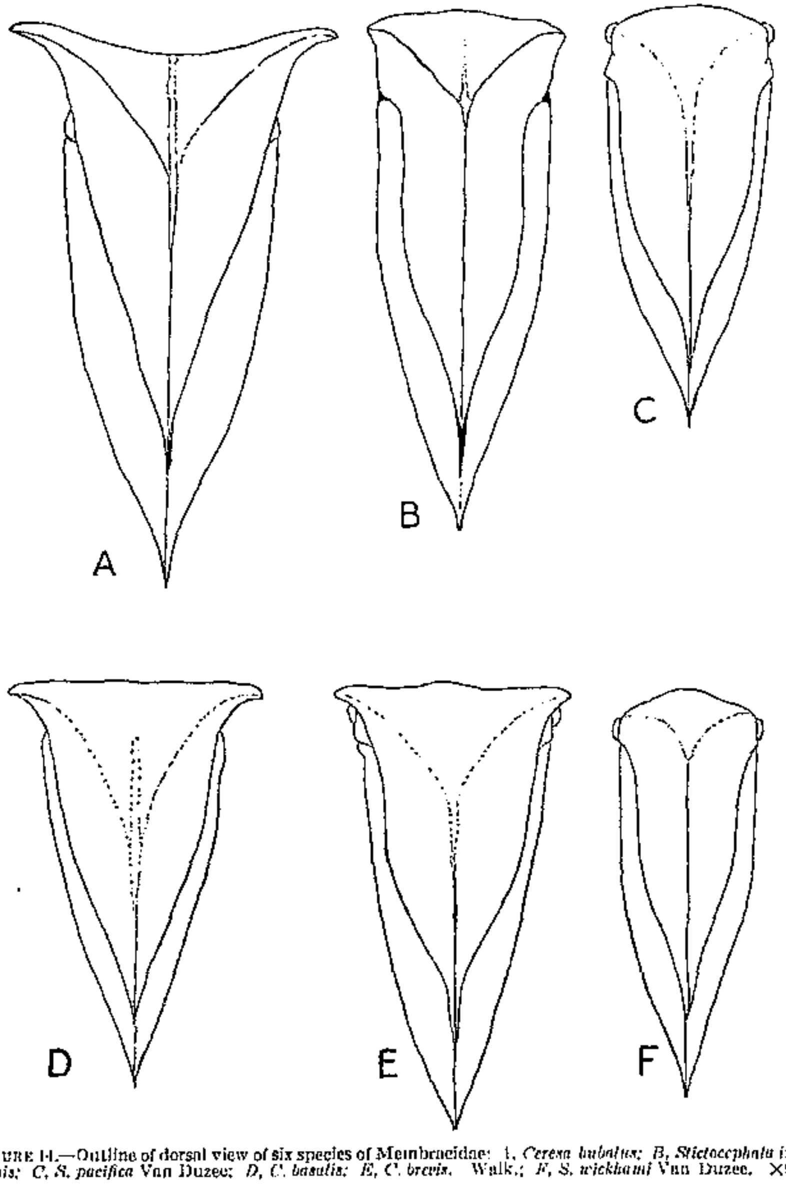

FIGURE 14.—Outline of dorsal view of six species of Membracidae: A, *Ceresa bubalus;* B, *Stictocephala inermis;* C, *S. pacifica* Van Duzee; D, *C. basalis;* E, *C. brevis.* Walk.; F, *S. wickhami* Van Duzee. ×9.

earlier in the morning than do those of *S. inermis.* Summarized records of the hourly hatching observed in the insectary in 1924 and 1925 are shown in table 11.

TABLE 11.—*Number of eggs of Ceresa basalis hatching daily and hourly in the insectary, Yakima, Wash., 1924 and 1925*

Date	Number of eggs hatched during the hour ended at—							Total	Percent of total	Temperature in °F. at—						
	7 a.m.	8 a.m.	9 a.m.	10 a.m.	11 a.m.	12 m.	1 p.m.			7 a.m.	8 a.m.	9 a.m.	10 a.m.	11 a.m.	12 m.	1 p.m.
1924																
May 4	0	0	0	1	0	0	0	1	0.15	40	48	51	52	50	55	54
5	0	0	0	0	17	4	0	21	3.13	38	50	54	58	51	61	61
6	0	0	0	1	38	22	11	72	10.73	44	48	52	58	65	70	71
7	0	0	8	37	18	10	0	73	10.88	47	55	61	63	65	68	71
8	0	50	57	31	0	0	0	138	20.57	51	60	67	74	78	80	81
9	2	101	32	6	2	0	0	143	21.31	58	65	72	78	82	85	87
10	0	97	21	5	0	0	0	123	18.33	60	67	75	83	86	89	90
11	0	80	13	0	0	0	0	93	13.86	61	68	80	85	87	90	92
12	1	5	1	0	0	0	0	7	1.04	67	76	81	83	85	87	92
13	0	0	0	0	0	0	0	0	0	60	74	81	84	87	88	90
Total	3	333	132	81	75	36	11	671	...							
Percentage of total	0.44	49.63	19.67	12.07	11.18	5.37	1.64		...							
1925																
May 5	0	1	11	1	1		...	14	7.37	55	61	68	76	78	...	...
6	5	0	0	0	0		...	5	2.63	57	65	73	76	80	...	...
7	0	0	0	0	0		...	0	0	45	45	46	46	46	...	...
8	0	0	0	0	0		...	0	0	44	43	44	44	44	...	...
9	0	2	2	1	1	...	...	6	3.16	49	54	58	62	64	...	...
11	5	18	4	7	3		...	37	19.48	53	55	59	64	68	...	...
12	4	10	19	7	0	...	...	40	21.05	51	56	60	65	70	...	...
13	6	33	0	1	0		...	40	21.05	57	61	65	70	75	...	...
14	3	21	3	1	0	...	...	28	14.74	61	63	70	76	80	...	...
15	0	8	3	0	0		...	11	5.79	57	63	70	75	70	...	...
16	0	5	0	0	0		...	5	2.63	65	67	70	74	76	...	...
17	0	1	1	0	0		...	2	1.05	58	61	65	70	73	...	...
18	0	0	1	1	0	...	...	2	1.05	59	60	63	63	62	...	...
Total	23	108	35	19	5	...		190								
Percentage of total	12.11	56.84	18.42	10.00	2.63											

NYMPHAL PERIOD

The newly hatched nymphs of *C. basalis* have a tendency to remain for several hours upon the underside of the twigs and do not fall immediately to the ground as do the nymphs of *S. inermis*. By midday, however, they have all disappeared from the trees.

Observations made in the insectary in 1925 on the development of 36 nymphs are shown in table 12. The total nymphal period ranged from 62 to 80 days, with an average of 70.1 days.

TABLE 12.—*Length of the nymphal instars of 36 individuals of Ceresa basalis hatched from May 11–17, inclusive, 1925, at Yakima, Wash.*

Item	First instar	Second instar	Third instar	Fourth instar	Fifth instar	Total nymphal period
EGGS HATCHED MAY 11 AND 12						
	Days	*Days*	*Days*	*Days*	*Days*	*Days*
Maximum	18	20	15	22	17	80
Minimum	9	11	10	11	11	62
Average	11.8	13.6	12.8	16.0	14.6	68.8
EGGS HATCHED MAY 13 AND 14						
Maximum	12	21	14	18	16	78
Minimum	10	16	9	9	11	63
Average	11.5	18.2	11.9	15.4	14.6	71.6

TABLE 12.—*Length of the nymphal instars of 36 individuals of Ceresa basalis hatched from May 11–17, inclusive, 1925, at Yakima, Wash.*—Continued

EGGS HATCHED MAY 15 AND 17

Item	First instar	Second instar	Third instar	Fourth instar	Fifth instar	Total nymphal period
	Days	*Days*	*Days*	*Days*	*Days*	*Days*
Maximum	18	17	14	16	19	73
Minimum	11	13	9	11	12	69
Average	14.8	15.5	11.3	13.3	15.7	70.7
Maximum for all	18	21	15	22	19	80
Minimum for all	9	11	9	9	11	62
Average for all	12.2	15.0	12.3	15.3	14.8	70.1

ADULT STAGE

Most of the nymphs change to adults in July, the earliest definite record being July 11. By the middle of the month adults are usually out in numbers, and they have been found in the field until October 8.

The earliest record of egg deposition for *C. basalis* is one for August 13, 33 days after the first adults matured that year, so there seems to be a preoviposition period of approximately a month, as in the case of *Stictocephala inermis*. With *C. basalis*, however, oviposition continues later into the fall than with *S. inermis*.

OVIPOSITION

Females have been observed depositing eggs from 9 a.m. to 6 p.m., and few, if any, eggs are deposited outside these hours.

As with *Stictocephala inermis*, the eggs of *Ceresa basalis* are deposited in water sprouts arising at the bases of the trees and in the twigs that hang down toward or into the alfalfa cover crop, but seldom higher in the trees than 6 or 7 feet from the ground. Eggs are also laid in nursery stock and young orchard trees.

The eggs are deposited in the upper side of twigs running more or less horizontally, but on twigs or young trees standing vertically or nearly so they may be found on any side though in greater numbers on the south side. There is often an overlapping or intermingling of oviposition scars of this species and of *Stictocephala inermis* and *Ceresa bubalus*, but the majority of *basalis* egg scars are beyond those of *inermis* and *bubalus* in newer, softer wood. As mentioned previously, many egg pouches are made in or near the terminal growth of twigs not more than one eighth of an inch in diameter, where there is insufficient wood to stand such wounds without disastrous results to both the twigs and the eggs deposited in them.

The eggs are inserted through the bark and much deeper into the wood than are the eggs of *S. inermis*. Although the eggs are deeply placed, the margins of the wounds are spread so wide that the tip ends of the eggs are often visible (fig. 7, *A*).

Counts of the eggs in 671 egg pouches showed a range of from 1 to 38 with an average of 19.9 (table 13).

TABLE 13.—*Number of eggs per pouch deposited by Ceresa basalis, Yakima, Wash., 1924–27*

Number of eggs per pouch	Number of pouches	Number of eggs per pouch	Number of pouches	Number of eggs per pouch	Number of pouches	Number of eggs per pouch	Number of pouches
1	1	11	16	21	25	31	8
2	1	12	21	22	42	32	2
3	1	13	17	23	43	33	2
4	2	14	23	24	32	34	2
5	5	15	31	25	39	35	5
6	8	16	26	26	28	36	2
7	12	17	25	27	27	37	3
8	16	18	44	28	26	38	1
9	7	19	26	29	9		
10	15	20	55	30	23		

Total pouches 671
Total eggs 13, 334

Average number of eggs per pouch 19. 9

Repeated observations have failed to indicate that there is any difference in the method of oviposition between this species and that already described for *S. inermis*. Instead of cutting the supplementary slits, however, as in the case of *inermis*, this species withdraws the ovipositor after having cut the longitudinal slit, rests a few minutes, and then commences depositing her eggs as described for *S. inermis*, the first egg in the slit being placed in the end last completed. The length of time required in depositing an egg is about the same as for *inermis*, 45 to 60 seconds for each egg, but since on an average about 20 eggs are placed in each wound, instead of the 6 in the case of *inermis*, the time necessary for *C. basalis* to complete an egg pouch is about three times as long.

Because of difficulties encountered in rearing the insects, the egg-laying capacity of individual females was not ascertained. It seems probable, however, that they lay as many as *S. inermis*, which is reported (*17*) to lay as many as 252 eggs each.

CERESA BUBALUS FAB.

The buffalo tree hopper, *Ceresa bubalus*, is rare, compared with *Stictocephala inermis* and *C. basalis*, in most places in the Yakima Valley. In certain other localities, however, it equals these in numbers, and in collections made at Parma, Idaho, *C. bubalus* predominated. Although this species is the largest of those studied and its injury more severe than that of *S. inermis*, it is so scarce in most localities that it is of less economic importance than either *S. inermis* or *C. basalis*. On account of its scarcity in the Yakima Valley few observations of importance were made upon it.

It is readily distinguished from *S. inermis* and *C. basalis* by its larger size and its large pronotal horns (fig. 14, *A*; pl. 4, *A*), and from *C. basalis* also by the lack of the dark coloring on the legs and ventral side of the body, which prevails in *basalis*.

DISTRIBUTION

Ceresa bubalus is one of the most widely distributed of the Membracidae in this country, having been recorded in nearly all of the States, except those in the extreme Southeast, and from most of the southern Canadian Provinces. It is generally recognized as perhaps the most injurious of all the Membracidae.

SYNONYMY AND COMMON NAME

Fabricius (*8, p. 14*) described this species in 1794, placing it in Germar's *Membracis*. In 1803, however, he changed the species to the genus *Centrotus* (*9, p. 20*). In 1840 Blanchard (*2, p. 181*) changed it back to the genus *Membracis*, but in 1846 Fairmaire (*10, p. 286*) placed it again in the genus *Centrotus*. In 1851 Walker (*29, p. 531*) placed it tentatively in the genus *Ceresa*, an allocation which was confirmed by Uhler in 1862, as reported by Harris (*16, footnote, p. 221*).

This species is commonly called the "buffalo tree hopper" on account of its high pronotum and the hornlike projections of the anterior angles of the pronotum which give it a fancied resemblance to a male buffalo.

The more important synonymy is as follows:

Membracis bubalus Fabricius, 1794 (*8, p. 14*)
Centrotus bubalus Fabricius, 1803 (*9, p. 20*)
Membracis bubalus Blanchard, 1840 (*2, p. 181*)
Centrotus bubalus Fairmaire, 1846 (*10, p. 286*)
Ceresa ? bubalus Walker, 1851 (*29, p. 531*)
Ceresa bubalus Uhler, 1862 (*16, p. 221*)

CHARACTER AND IMPORTANCE OF INJURY

The oviposition scars of *C. bubalus* are conspicuously different from those of either of the other species studied (pl. 6, *B*). The incisions are made in pairs, two short cuts semicrescentric and parallel, in each of which from 6 to 12 eggs are deposited. The cuts, which prevent the wood from growing over the wounds, increase in size from year to year, causing extremely ugly scars and roughened, gnarled twigs (pls. 5, *A*, *b*, and 6 *A*, *a*, *B*).

Badly infested twigs are dwarfed and weakened and so are easily broken by the wind. As in the case of the scars of the associated species *C. basalis*, these pronounced lesions often furnish suitable and convenient hiding places for the woolly apple aphid and for the overwintering eggs of the green apple aphid.

Goodwin and Fenton (*15*), in a histological study of the pathological changes produced in the plant tissue resulting from these malformations, determined that owing to the formation of corky layers of cells on either side of the lesions the wounds failed to heal and that as the surrounding wood continues to grow the wounds become deeper and wider, causing the wood between the cuts to slough off. They state:

> Altogether, mechanical injury is very severe and there are evidences that decay often sets in due to these wounds. While these may eventually heal over, the organisms have already entered the heartwood, and ultimately this secondary injury may kill the entire limb.

FOOD PLANTS

The present studies of this species have been limited, and the nymphs have not been observed. It is probable, however, that their chief food plant in the orchard is alfalfa. They may also feed on sweetclover.

Funkhouser (*12*) reports *Ceresa bubalus* as common on grasses and low shrubs and as feeding upon succulent herbs, particularly sweetclover. Brittain (*3*) reports it as feeding upon sheep sorrel (*Rumex acetosella*), Canada thistle (*Cirsium arvensis*), clover (*Trifolium repens*), goldenrod (*Solidago* spp.), curled dock (*Rumex crispus*), plantain (*Plantago major*), and dandelion (*Taraxacum officinale*).

Severin (*25*) reports the adults as feeding and ovipositing upon apple, pear, plum, elm, poplar, willow, and boxelder trees; the nymphs as feeding on succulent weeds.

Pettit (*21*) has observed a species of tree hopper, probably *bubalus*, as seriously injurious in Michigan to 1-year-old and 2-year-old fruit trees set out in alfalfa land, while an adjoining lot of trees set in clean cultivated land was entirely free from infestation.

COMPARISON OF OVIPOSITORS

The ovipositors of the three species, *Stictocephala inermis*, *Ceresa basalis*, and *C. bubalus*, were examined, inasmuch as these three species

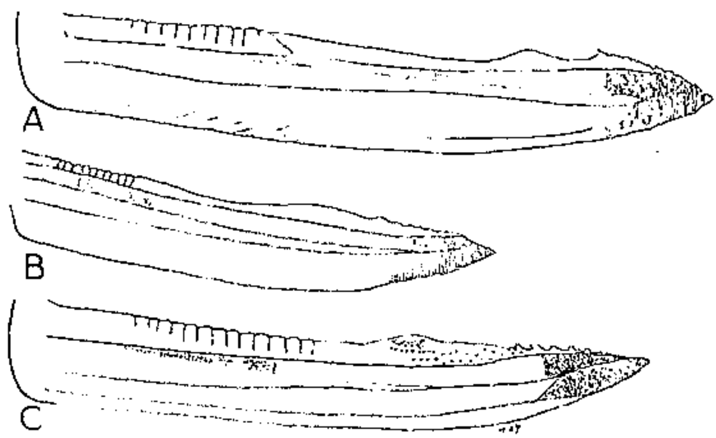

FIGURE 15.—Ovipositors: *A*, *Ceresa basalis*; *B*, *Stictocephala inermis*; *C*, *Ceresa bubalus*. All × 25.

make quite distinct incisions in which to deposit their eggs. Although *C. basalis* is the smallest of the three, it has the longest ovipositor (fig. 15, *A*) and makes the deepest incision. *Stictocephala inermis*, which makes the most superficial incision, has the shortest ovipositor (fig. 15, *B*), and *C. bubalus*, the largest of the three species, which makes the double, medium deep cuts, has an ovipositor midway in length between those of the other two (fig. 15, *C*). The average length of several ovipositors of each species was found to be as follows: *C. basalis*, 3.7 mm; *C. bubalus*, 3.4 mm; and *S. inermis*, 2.7 mm. The ovipositors of the species of *Ceresa* are also somewhat broader than that of *S. inermis*.

The sharp sawlike edge of the tip of the ovipositor readily accounts for the ability of the females to cut their oviposition lesions

CERESA ALBIDOSPARSA STÅL

In March 1927, 1-year-old seedling pear trees were found with membracid eggs inserted in the buds. It was apparent that these must be the eggs of some species other than those previously studied. Samples of these twigs were brought to the laboratory and kept for observation and hatching of the eggs. The eggs proved to be those of *Ceresa albidosparsa*.

DISTRIBUTION

C. albidosparsa Stål is recorded by Funkhouser (*13*) as occurring in California, Nevada, Texas, and British Columbia. This is therefore the first published record of its occurrence in the Pacific Northwest. It is probably a western species, since there is no record of its having been found elsewhere. It is probable that it is harmless, since its eggs are deposited in the buds, where apparently they cause little, if any, damage.

HISTORY

Ceresa albidosparsa was originally described by Stål in 1869 (*26, p. 245*), since which time it has been referred to only eight times in entomological literature. These references are all under the name given above, as this tree hopper has not been confused with other species or described under any other names. Little is known of its life history and habits, and it has no common name.

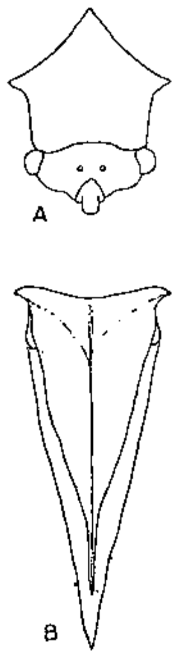

FIGURE 16.—*Ceresa albidosparsa*: *A*, Front view; *B*, dorsal view. ×6.

DESCRIPTION OF ADULT

Pale green; 8 mm in length; with short, curved, red-tipped pronotal horns (fig. 16).

POSITION OF EGGS

The eggs are deposited singly or in small groups of 2 or 3 in the buds, either at the base or among the bud scales (fig. 17). Most of them are placed in terminal buds or in buds close to the tips of the twigs. As many as a dozen eggs may be found in a single bud, though usually there are only about half that number.

FIGURE 17.—Eggs and empty hatching membranes of *Ceresa albidosparsa* in buds of 1-year-old seedling pear tree. ×2.

HATCHING

Just previous to hatching, the eggs protrude from the bud about two thirds of their length. This may be partly due to the effect of the extending bud scales, which at this time are pushing out rapidly.

The time required for the emergence of the nymphs from the eggs was about 13 minutes in the few cases observed.

The eggs of *C. albidosparsa* seem to hatch earlier in the morning than the eggs of other species observed. Possibly this is due to the fact that increasing temperatures can more readily affect the eggs in their semiexposed position in the buds than is possible with those within the bark and outer wood.

NYMPHAL INSTARS

Several nymphs in vials were reared through the first instar on alfalfa. These are readily distinguished from the first-instar nymphs of other species by their much lighter color, yellowish heads, and white eyes. The agility of their movements also readily distinguished them from all other species. While nymphs of other species walked slowly from place to place, these darted here and there with apparent haste.

A close study of the arrangement of tuberosities and hairs on the head and face of newly hatched nymphs (fig. 18) revealed nothing especially different from their arrangement in other species, particularly *C. basalis* (fig. 8, *B*). Except for the white eyes and the cream-yellow color of the head, these nymphs resembled those of the other species studied.

Nymphs hatched from April 16 to 26, 1927, from twigs kept since March 29 in the laboratory, at room temperature. Outdoor hatching occurred from May 6 to 10. From these one adult reached maturity on July 18, after passing through the five instars characteristic of the other species of Membracidae. Moltings took place as follows: May 24–25, June 3–6, June 9–11, June 20–25, and July 18. The total length of the period of the nymphal instars was between 69 and 73 days.

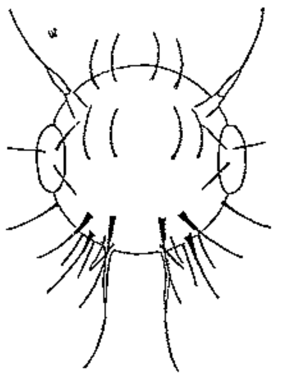

FIGURE 18.—Front view of head and face of first instar nymph of *Ceresa albidosparsa*. ×45.

HELIRIA RUBIDELLA BALL

Heliria rubidella was first described by Ball (*1, p. 28*) from Colorado in 1918. Since 1926 it has been found in considerable numbers on apple trees at Wenatchee, Wash., as reported by Yothers, Webster, and Spuler in 1929 (*35, p. 269*) and by the writer in 1930 (*33, p. 1, 2, 12; 34, p. 15*).

The eggs of this membracid are laid in the apple twigs, one in each of two more or less closely placed parallel slits.[3]

The nymphs hatch late in April and early in May. Unlike other species studied, the nymphs do not fall to the ground upon emerging, but remain on the twigs throughout their nymphal stages, feeding upon the plant juices and reaching maturity in early June.

The adults (pl. 7, *A–E*) feed, mate, and oviposit on the twigs, spending most of their lives there except for rare flights to neighboring trees. Inasmuch as the insects do not feed upon the cover crop or deposit their eggs in any of the cover-crop plants, it is evidently of no consequence in the life of the insect.

Hundreds of individuals (pl. 7, *E*) are sometimes found on sickly branches of apple trees, particularly of the Stayman Winesap variety. This, at first, seemed to indicate that these insects were responsible for the unhealthy condition of the branches (pl. 8). Later, however, it was decided that the presence of the insects was probably due to an especially attractive odor given off by the limbs and that the presence

[3] The writer is indebted to P. B. Allen, Jr., temporary assistant at the Wenatchee, Wash., laboratory of the Bureau of Entomology from 1930 to 1932, for this discovery and for other observations on this species which had not yet been reported.

of the insects was a result and not the cause of the trouble, although the insects do feed upon the sick branches, thereby doubtless hastening their death.

ASSOCIATED SPECIES OF MEMBRACIDAE

The following associated species have been recorded from specimens collected in these studies, from other collections, and from literature: *Ceresa albidosparsa*,[4] *C. basalis*, *C. borealis* Fairm.,[4] *C. brevis* Walk.[4] (fig. 14, *E*), *C. bubalus*,[4] *C. femorata* Fairm.,[4] *C. taurina* Fitch.,[4] *Stictocephala franciscana* Stål, *S. inermis*,[4] *S. pacifica* Van D. (fig. 14, *C*), *S. wickhami* Van D. (fig. 14, *F*), *Campylenchia latipes* Say, and *Heliria rubidella* Ball.[4]

Stictocephala pacifica, according to Van Duzee,[5] probably does not occur in the interior country of the Pacific coast at all, and records of this species in the interior districts of Washington, Idaho, Oregon, or British Columbia are probably based on erroneous identifications. *Stictocephala wickhami*, while recognized by some students of these groups, and found in collections as such, is probably comparatively rare, or is not readily separated from *inermis*. *Ceresa brevis* is represented by a few specimens determined by Van Duzee from Idaho, which had previously been determined as *C. borealis*. Funkhouser [6] has recognized both *C. femorata* and *C. taurina*.

Campylenchia latipes has been found in considerable numbers throughout the Pacific Northwest wherever observations have been made upon species of the genera *Ceresa* and *Stictocephala*. Like them, it is found on the alfalfa cover crop in orchards, upon which it feeds throughout its nymphal stages and also as an adult. This species has been observed incidentally from time to time in the studies of the other forms. Individuals of this species reach maturity earlier than the other membracids, adults having been taken as early as June 9, and in considerable numbers by June 19.

DISSEMINATION

Although capable of flight, tree hoppers are not ordinarily seen flying about in the fields and orchards, although when disturbed, as by the approach of a person, they take flight so suddenly that it is often difficult to watch their movements. They seldom fly higher than 8 or 10 feet, or farther than 100 feet at one flight. The distance flown by a number observed was about 50 to 75 feet. Presumably they fly considerable distances during their 60 or more days of adult life. This is apparently their only natural means of dissemination, since in their nymphal instars they never move even from one plant to another.

Infestation of new areas, at least at considerable distances, is probably very largely through egg-infested nursery stock and graft scions. In the adult stage the insects might occasionally be carried by vehicles passing through orchards or fields, or in fruit boxes or on other orchard equipment. Since the adults are extremely shy, however, it is very improbable that they are often distributed in this way.

[4] Not recorded by Funkhouser (*13*) as occurring in the Pacific Northwest (Washington, Oregon, and Idaho).

[5] In correspondence with the writer.

THE RELATION OF ANTS TO NYMPHS

Much has already been written by others upon the interesting subject of attendance of ants upon the nymphs and adults of membracids. Funkhouser (*12*) reports that while individuals of the genera *Ceresa* and *Stictocephala* have been known to be attended by ants, the latter genus has never been known to give off the anal fluid. The writer has observed attendance by ants upon *Stictocephala inermis* and *Ceresa basalis* in outdoor rearing cages set over alfalfa plants. Probably more than one species of ant attends the nymphs in this part of the country, but only one species has been definitely determined (*Myrmica rubra scabrinodis* var. *sabuleti* Meinert).

Considerable numbers of this species of ant have been observed associating with the nymphs in the cages mentioned. They were observed waving their antennae and stroking the posterior extremities of second, third, and fourth instar nymphs, causing the nymphs to void a clear, colorless liquid from the anal aperture, which the ants then proceeded to feed upon with apparent relish.

NATURAL CONTROL

Mention has already been made of the natural mortality to which the egg stage, especially of *C. basalis*, is subject. In the nymphal stages the tree hoppers are also subject to a considerable mortality. In dropping from the trees, in the twigs of which the eggs are laid, many nymphs fall on, or are blown by the wind to, utterly barren ground and are unable to reach suitable food plants; still others fall into irrigation ditches and are lost. Of the many, many thousands of nymphs that hatch from each tree in heavily infested orchards, only a comparatively few survive and reach maturity.

PARASITES

Two species of hymenopterous egg parasites, *Gonatocerus* n. sp.[6] and *Tetrastichus* sp.,[7] have been reared from the eggs of *Stictocephala inermis;* but since these are so rare they affect little control.

OTHER ENEMIES

Of the various species of spiders observed feeding upon the hatching eggs and emerging nymphs, two species have been determined as *Philodromus minuta* Bks.[7] and *Dendryphantes militaris* Hentz.[7] These spiders and other undetermined species are commonly observed throughout the hatching period upon the twigs from which *S. inermis* nymphs are emerging, and have often been seen devouring the tender young nymphs while they were emerging from the eggshells.

A species of mite belonging to the genus *Seius* [8] was found in considerable numbers associated with the overwintering tree-hopper eggs, and was doubtless responsible for the destruction of a great many of the eggs, inasmuch as discolored, empty, shriveled eggshells were almost always associated with the presence of these mites in the egg pouches.

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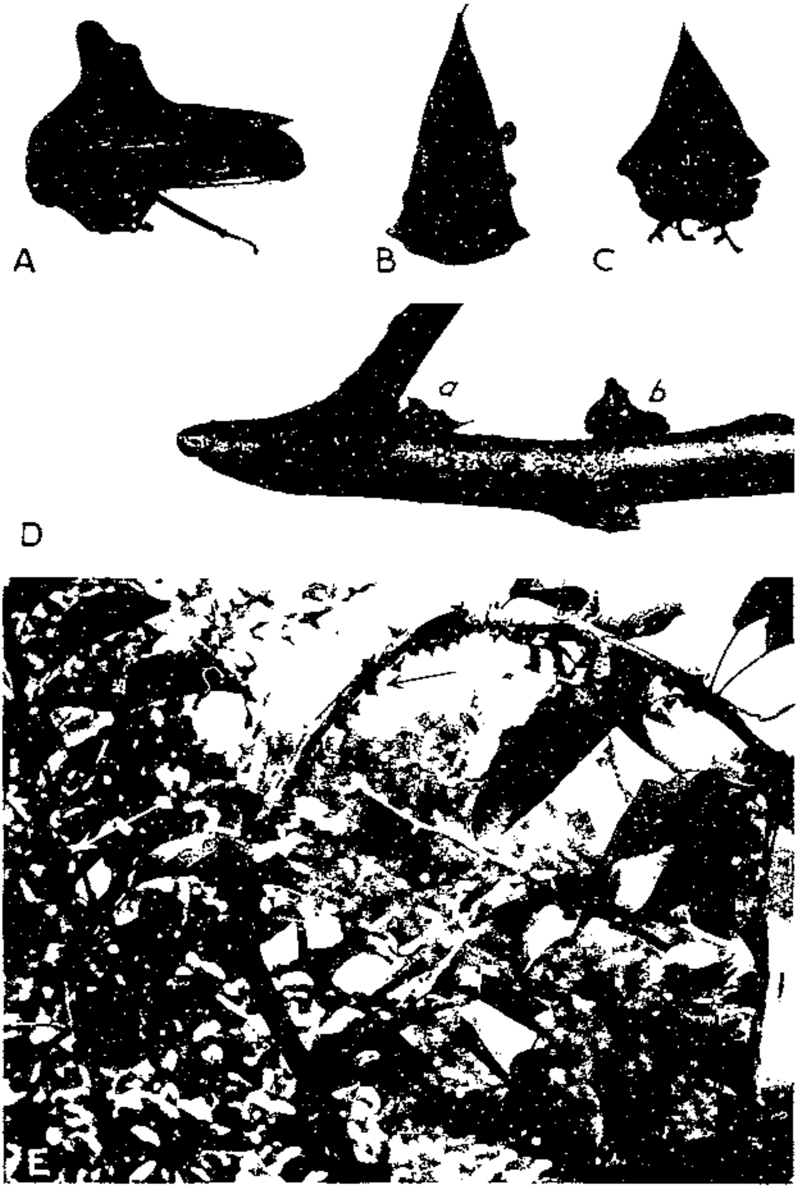
[6] Determined by A. B. Gahan.
[7] Determined by A. R. Shoemaker.
[8] Determined by H. E. Ewing.



HELIRIA RUBIDELLA BALL.

A, Side view. B, Dorsal view. C, Frontal view. × 1. D, Fifth-instar nymph, *a*, and adult, *b*. × 1¼. E, Characteristic group of adults on apple twig. × ¾.

Dying branch of Stayman Winesap apple tree at Wenatchee, Wash., characteristic of type of tree infested by *[illegible] rubidella*.

At least two coccinellids, *Adalia bipunctata* L.[9], and *Hyperaspis quadrivittata* Lec.[10] have been observed feeding upon the hatching nymphs. Both of these have been seen devouring numbers of the emerging nymphs, one after another, within a few minutes' time.

A single specimen of *H. quadrivittata* was placed in a Petri dish at 1:15 p.m. and given 20 newly hatched nymphs for food. It ate 15 of them during the first 15 minutes, and still others during the next 15 minutes. At 2:15 it was given 20 more nymphs, several more of which it had eaten by 3:15.

An ant, *Formica fusca fusca* var. *argentia* Wheeler [10], has been noted a number of times eating the hatching nymphs.

Another ant, *Myrmica rubra scabrinodis* var. *sabuleti* Meinert, was often seen in the cages carrying portions of dead nymphs about in its mouth, although it was not actually seen eating them. It is reasonable to suppose that ants are responsible for the death of many of the nymphs, since they are invariably associated with them, and the mortality of the nymphs is very high.

Adults of *Ceresa bubalus*, *C. basalis*, and *Stictocephala inermis* collected at Parma, Idaho, in August 1924 were badly infested with a red mite, determined by H. E. Ewing as "parasitic larvae of the genus *Achorolophus* of the family Erythraeidae." Great numbers of these mites were present under the tegmina and on most of the ventral spaces on the body. It was noted that the more heavily infested individuals were comparatively sluggish and therefore more readily captured by hand. Only rarely have these mites been found on membracids in the Yakima Valley.

Coccinellid and syrphid larvae of undetermined species have been observed feeding upon the hatching nymphs in the orchard.

Other species of predatory insects, such as those of the genera *Hemerobius*, *Chrysopa*, and *Oecanthus*, doubtless feed upon the emerging nymphs, since they are occasionally present during the last part of the hatching season.

No observations have been made as to whether birds feed upon the tree hoppers under discussion, but Wildermuth (*30*) records several species of birds as feeding upon *S. festina* in alfalfa fields in Arizona. *S. festina* is considerably smaller than any of the species studied here, but it is probable that a few individuals of these larger species are devoured by certain birds. Wildermuth also records toads as predatory on *S. festina*, and it is probable that toads also help check the increase of the northwestern species.

NATURAL PROTECTION

Little protective resemblance can be claimed for the shape of the species here discussed, at least under their present acquired environment. The general green color, however, gives them certain protection among the green food plants upon which they feed, and among which they spend most of their lives. This greenish coloring also may be of incidental protection to them while they are resting on the petioles of leaves and on the leaves themselves, but it probably is of little value to them when they are on the twigs ovipositing or resting.

[9] Determined by H. S. Barber.
[10] Determined by S. A. Rohwer.

The habit of remaining quiet for hours at a time is doubtless of no little protective value to the adults.

The almost universal position assumed by the nymphs of *Heliria rubidella* behind the buds, which they closely resemble in both color and shape, evidently affords them considerable protection.

The habit of nymphs and adults of stepping rapidly around to the opposite side of the twig or other object, when disturbed, is also of protective value.

The hard pronotum with its sharp posterior end and, in the species of *Ceresa*, the more or less sharp humeral horns doubtless afford considerable protection.

As Wildermuth (*30*) has pointed out, the habit of exploding a bubble of liquid from the tip of the abdomen when disturbed is probably also of protective value when this bubble is exploded in the face of an enemy.

PREVENTIVE AND CONTROL MEASURES

SPRAYING AGAINST THE EGGS

Lovett (*18*) suggested the use of 8 gallons of a heavy miscible oil to 100 gallons of water, but expressed a reasonable doubt that such a spray could reach the egg masses hidden underneath the bark. The studies conducted by the writer, as indicated earlier in this bulletin, have shown that the eggs of the tree hoppers are sufficiently exposed to be reached by contact sprays, and numerous tests were conducted with such materials.

LABORATORY TESTS

Tests of various materials of possible value against the eggs of *Stictocephala inermis* were conducted in the laboratory in 1923 and 1924. Twigs containing tree-hopper eggs were brought in from the orchard and were sprayed with such materials as were being tested in certain experiments (*19*) for the control of red spiders [11] and the San Jose scale.[12] Spraying was done with a hand atomizer, the twigs being thoroughly drenched on all sides, after which they were placed with their cut ends in jars of water and kept until sufficient time had elapsed for the eggs to hatch. The results of these tests, which are shown in tables 14 and 15, indicated that lime-sulphur at the usual dormant strength is not very effective against the eggs of the tree hoppers, that lubricating oil emulsions at 4 percent of actual oil showed a mortality of 90 to 100 percent (including mortality from natural causes); that miscible oils are as effective (at equivalent strengths) as the lubricating-oil emulsions; that the distillate oils are less effective than the more viscous lubricating oils; and that kerosene emulsion at 8 to 16 percent is about equivalent to the lubricating-oil emulsions at 4 percent. It was also evident that applications made while the eggs were dormant were fully as effective as applications made as time for hatching approached.

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[11] *Paratetranychus pilosus* C. and F. and *Bryobia praetiosa* Koch.

[12] *Aspidiotus perniciosus* Comst.

TABLE 14.—*Laboratory tests of dormant sprays on the eggs of Stictocephala inermis, Yakima, Wash., 1923*

Test	Materials used	Dilution	Date eggs were— Sprayed	Date eggs were— Counted	Total eggs	Condition of eggs at count: Hatched	Condition of eggs at count: Dead	
					Number	*Number*	*Number*	*Percent*
		°Baumé						
A	Lime-sulphur (26° Baumé) concentrate	3	Mar. 17	May 15	289	147	142	49.1
B	do	4	do	May 16	351	113	238	67.8
C	do	5	do	May 17	449	89	360	80.2
		Percent oil						
D	Lubricating-oil emulsion (soap emulsifier)	2	Mar. 14	May 12	272	93	179	65.8
E	do	4	do	do	269	0	269	100.0
F	Material used in test D, plus ¼ percent cresol [1]	2	do	May 4	379	64	315	83.1
G	Material used in test D, plus ½ percent cresol	2	do	May 12	179	24	155	86.6
H	Material used in test D, plus 1 percent cresol	2	do	do	338	28	310	91.7
I	Material used in test E, plus ¼ percent cresol	4	do	May 4	440	0	440	100.0
J	Material used in test E, plus ½ percent cresol	4	do	May 12	306	0	306	100.0
K	Material used in test E, plus 1 percent cresol	4	Mar. 17	May 15	342	0	342	100.0
L	Material used in test E, plus 6 percent cresol	6.5	Mar. 14	May 12	340	0	340	100.0
M	Crude oil emulsion	2.67	Mar. 17	May 17	438	64	374	85.4
N	do	6.67	do	do	348	8	340	97.7
O	do	10	do	do	350	33	317	90.6
P	Crude oil emulsion, plus ½ percent cresol	2.67	do	do	267	7	260	97.4
R	Commercial distillate-oil emulsion	4.1	do	do	385	182	203	52.7
KK	Kerosene emulsion	8	Mar. 20	May 2	362	27	335	92.5
ZZ	do	16.67	do	do	280	20	260	92.9
CK	Untreated			Apr. 30 / May 2	952	791	161	16.9

[1] The cresol used was cresylic acid, 97-99 percent, pale.

TABLE 15.—*Laboratory tests of dormant sprays on the eggs of Stictocephala inermis, Yakima, Wash., 1924* [1]

SPRAYED MAR. 7, EXAMINED MAY 1

Test no.	Material used	Dilution	Total eggs	Condition of eggs at count: Hatched	Condition of eggs at count: Dead	
			Number	*Number*	*Number*	*Percent*
		° Baumé				
1	Lime-sulphur (30° Baumé concentrate)	4	225	135	90	40.0
2	do	5	220	125	95	43.2
		Percent oil				
3	Lubricating-oil (brown neutral) emulsion (soap emulsifier)	2	260	55	205	78.8
4	Lubricating-oil (red engine) emulsion (soap emulsifier)	2	295	70	225	76.3
5	do	3	315	65	250	79.4
6	do	4	240	20	220	91.7
7	Lubricating-oil (red engine) emulsion (casein-lime emulsifier)	2	220	45	175	79.5
8	Miscible oil	2	185	35	150	81.1
9	do	3	315	20	295	93.7
10	Commercial lubricating-oil (brown neutral) emulsion	2	280	50	230	82.1
11	Commercial spray oil	2.3	230	55	175	76.1
12	do	4	235	25	210	89.4
13	Untreated		315	250	65	20.6

[1] For specifications of spray materials see U.S. Dept. Agr. Tech. Bul. No. 25, pp. 29-32 (*19*).

TABLE 15.—*Laboratory tests of dormant sprays on the eggs of Sticlocephala inermis, Yakima, Wash., 1924*—Continued

SPRAYED APR. 4, EXAMINED MAY 15–17

Test no.	Material used	Dilution	Total eggs	Condition of eggs at count: Hatched	Dead	
		° Baumé	*Number*	*Number*	*Number*	*Percent*
68	Lime-sulphur (30° Baumé concentrate)	5	186	112	74	39.8
R	....do	6	376	107	209	55.6
		Percent oil				
69	Lubricating-oil (brown neutral) emulsion (soap emulsifier)	2	227	44	183	80.6
U	Lubricating-oil (brown neutral) emulsion (soap emulsifier)	3	427	6	421	98.6
70	Lubricating-oil (red engine) emulsion (soap emulsifier)	2	266	37	229	86.1
71	Lubricating-oil (red engine) emulsion (casein-lime emulsifier)	2	233	55	178	76.4
72	....do	3	281	48	233	82.9
73	Miscible oil	2	254	42	212	83.5
Y	....do	3	404	0	404	100.0
AA	....do	4	320	25	295	92.2
BB	Miscible oil, plus nicotine sulphate 1:600	4	662	5	657	99.2
75	Commercial oil emulsion	2	170	54	116	68.2
76	....do	3	414	18	396	95.7
CC	Untreated	...	386	227	159	41.2

A somewhat higher percentage of kill was obtained in the laboratory than in the field, partly because of the more thorough application of the spray. It is also possible that the slower evaporation under indoor conditions is conducive to greater penetration, and consequent greater lethal effect upon the insect.

ORCHARD TESTS

The results of field tests of various materials conducted in 1923 and 1925 are given in tables 16 and 17. In 1923 applications were made at two different times, first when the eggs were dormant, and later about a week before they began to hatch. While the percentages of kill in the field were somewhat lower, results were in general agreement with those obtained in the laboratory. The lubricating-oil sprays at a 4 percent strength, with or without the addition of lime-sulphur or of nicotine, were found quite effective in killing most of the eggs. Lime-sulphur at a 4° Baumé strength, on the other hand, appeared to be of little value.

TABLE 16.—*Orchard tests of dormant sprays on the eggs of Sticlocephala inermis, Yakima, Wash., 1923*

[Applications made with a power sprayer]

PLOT 1, SPRAYED MAR. 29, COUNTED MAY 19–22

Test no.	Material used	Dilution of actual oil	Total eggs	Condition of eggs at count: Hatched	Dead	
		Percent	*Number*	*Number*	*Number*	*Percent*
1	Lubricating-oil emulsion	2	351	206	145	41.3
2	Lubricating-oil emulsion, plus ¼ percent cresol	2	419	181	238	56.8
3	Lubricating-oil emulsion, plus ½ percent cresol	4	400	103	297	74.2
4	Distillate-oil emulsion	6	264	149	115	43.6
5	Untreated	...	381	334	47	12.3
	PLOT 2, SPRAYED APR. 10, COUNTED MAY 23–25					
1	Lubricating-oil emulsion	2	345	200	145	42.0
2	Lubricating-oil emulsion, plus ¼ percent cresol	2	360	209	151	41.9
3	Lubricating-oil emulsion, plus ½ percent cresol	4	511	53	458	89.6
4	Miscible oil	3	442	108	334	75.6

TABLE 17.—*Orchard tests of dormant sprays on the eggs of Stictocephala inermis in sprouts growing from the bases of tree stumps, Yakima, Wash., 1925*

[Sprayed with a bucket pump Apr. 7, examined May 13]

Test no.	Material as used	Total eggs	Condition of eggs at count		
			Hatched	Dead	
		Number	*Number*	*Number*	*Percent*
1	Lime-sulphur (28° Baumé concentrate) diluted to 4° Baumé	495	350	145	29.3
2	Lubricating-oil (brown-neutral) emulsion (casein-lime emulsifier) at 3 percent actual oil	355	50	305	85.9
3	Same material as test 2, at 4 percent actual oil	560	40	520	92.9
4	Material used in test 2, plus lime-sulphur (28° Baumé concentrate), the mixture to read 2° Baumé	545	35	510	93.6
5	Material used in test 2, plus lime-sulphur (28° Baumé concentrate), 1 gallon to 50 gallons	540	5	535	99.1
6	Material used in test 2, but at 6 percent actual oil, plus nicotine sulphate (40 percent), 1 part to 1,000 parts of the emulsion	525	0	525	100.0
7	Same as test 6, but with 3 percent actual oil	552	27	525	95.1
8	Untreated	305	250	55	18.0

No tests were made separately on the eggs of *C. basalis*, but counts were made of the eggs from orchards which had been given the regular dormant sprays for the control of the San Jose scale in early spring. In one orchard a 4 percent oil emulsion was used throughout, and in the second orchard a 4 percent oil emulsion was used in part of the acreage and lime-sulphur (4° Baumé) was used in the rest. The results of these counts are shown in table 18.

TABLE 18.—*Eggs of Ceresa basalis killed by orchard spraying for the San Jose scale, Yakima, Wash., 1925*

Treatment	Date eggs examined	Condition of eggs				Dead or overgrown [1]
		Alive	Hatched	Dead		
		Number	*Number*	*Number*	*Percent*	*Percent*
Engine-oil emulsion, 4 percent	Apr. 29 and May 5.	988	88	2,594	70.68	
Check	do	455	50	140	21.71	
Engine-oil emulsion, 4 percent	May 1	270	15	560	66.27	
Lime-sulphur, 4° Baumé	do	450	20	255	35.17	
Check	do	416	62	177	27.02	
Engine-oil emulsion, 4 percent	May 15 [2]	135	65	870	81.31	93.93
Lime-sulphur, 4° Baumé	do	150	370	225	30.20	50.34
Check	do	70	775	175	17.16	24.02

[1] Eggs overgrown are considered as dead in records for control.
[2] All eggs that could hatch had hatched by this date.

A factor to be considered in interpreting these results is that the portions of the trees where eggs of *C. basalis* were deposited, i.e., in sprouts growing about the base of the tree and in the terminal twigs of the low-hanging branches, are the portions of the trees most often slighted in the spraying.

SPRAYING AGAINST THE NYMPHS

Funkhouser (*12*) suggested the use of contact sprays against the soft-bodied nymphs, and this was tested in 1923. The alfalfa in four orchard blocks was sprayed with a power outfit on May 2, when the alfalfa was 12 to 18 inches high and the tree-hopper eggs had nearly all hatched. Four different materials were used in the plots as follows: (1) Nicotine sulphate 1 to 800 with a casein-lime spreader, one half pound in 50 gallons; (2) nicotine sulphate 1 to 800 in a 1 percent lubricating-oil emulsion; (3) lubricating-oil emulsion, 1 percent; and (4) lubricating-oil emulsion, 2 percent. No noticeable control resulted in any of the plots, probably because of the difficulty in wetting the lower portions of the plants, where the young nymphs feed. If the spraying could be done immediately after the alfalfa has been cut, it might be possible to wet the plants far enough down within the crowns to kill the nymphs, but this method promises little value.

CLEAN CULTURE

Since these membracids, with the exception of *Heliria rubidella*, feed exclusively throughout the nymphal period upon the more succulent vegetation growing in the orchard, such as alfalfa, sweetclover, and weeds, it is apparent that the elimination of all such food plants will be an effective control measure. Repeated observations made in the Yakima Valley have shown that orchards which are free of weeds suffer very little tree-hopper infestation except in trees on borders adjacent to alfalfa fields. Few instances were observed in which the hoppers traveled more than two tree rows from suitable food and protection, such as weeds or cover crops.

In the arid districts of the Pacific Northwest, however, a cover crop of some kind, usually alfalfa, has been found almost essential from the standpoint of general horticultural practice, and the loss sustained by the total elimination of cover crops would far exceed the gain from the repression of the tree hoppers. If other control measures were not available, however, the temporary elimination of cover crops might be worth considering in the case of a serious infestation.

If clean culture is likely to be practiced later on, sweetclover is preferable to alfalfa as a cover crop. Alfalfa is very persistent after once becoming established, and difficult to eliminate by cultivation. Sweetclover, on the other hand, is readily eliminated after the first two seasons.

OTHER POSSIBLE CONTROL METHODS

The pruning out and destruction of infested twigs is sometimes advised. In cases of severe infestation this is obviously impractical, and in the case of young trees it would often mean the removal of the entire tree. In light infestations, on the other hand, the tree hoppers are seldom sufficiently injurious to warrant the effort. In the course of the regular pruning process, however, any infested twigs noted might well be removed.

The use of hopperdozers, which has been suggested, for controlling the adult tree hoppers in alfalfa fields was reported by Wildermuth (*80*) as impracticable, as but a small part of the hoppers were captured. Hopperdozers would be altogether impractical in orchards, even if they were otherwise successful, on account of the presence of the trees and because the cover crop of uncut alfalfa or sweetclover would not permit their use at any time when the adults were present.

SUMMARY AND CONCLUSIONS

Considerable injury to fruit trees in the Pacific Northwest is caused annually by the egg-laying activities of several species of Membracidae commonly known as "tree hoppers." The more important of these, in the order of their economic significance, are *Stictocephala inermis*, *Ceresa basalis*, and *C. bubalus*. The last, the buffalo tree hopper, is generally credited with the injury caused by them all, but it is less important in the Pacific Northwest than either of the other two.

In the nymphal stages these membracids feed upon the alfalfa or sweetclover and possibly upon some of the succulent weeds growing in the orchards.[13] Their feeding upon these plants has caused no noticeable injury. The damage they cause results from the wounds cut into the twigs of fruit trees for the purpose of oviposition.

Eggs are deposited in apple, cherry, peach, pear, prune, willow, locust, poplar, and many other kinds of trees and shrubs. For the most part 1- and 2-year-old wood is used for egg deposition. An exception to this is the choice of the current season's growth by *C. basalis*.

Although the incisions are usually small, there are so many of them in cases of severe infestation that the growth of the tree is retarded. This is especially serious with 1- and 2-year-old trees. In the case of *C. basalis* the deep wounds made for egg deposition in the terminal portions of the twigs often cause these twigs to wither and die back for several inches.

The scars furnish suitable feeding places for the woolly apple aphid (*Eriosoma lanigerum*). The irritation caused by these aphids prevents the wounds from healing, and the unhealed wounds furnish entrance for fungous and other diseases.

The insects winter over in the egg stage only. These eggs are deposited from July to early October and hatch in April and early May the following spring. Upon hatching, the nymphs, excepting those of *Heliria rubidella*, fall to the alfalfa or such other cover crop or weeds as may be present. There they feed and pass through five instars, reaching maturity late in June or in July. The adults live about 60 days.

Ceresa bubalus deposits from 6 to 12 eggs in two short, parallel rows; *C. basalis*, about 20 eggs in straight, deep, longitudinal wounds; *Stictocephala inermis* deposits about 6 eggs in each tiny superficial scar; *C. albidosparsa* deposits eggs singly in buds; and *Heliria rubidella* deposits them singly in the bark.

Besides these species, there are several others associated with them, some of which are not readily distinguishable from them, but owing to their scarcity they are of little economic importance.

Of the various methods of control suggested or tried, spraying the eggs with a 4-percent oil emulsion or miscible oil is the most practical and satisfactory measure. While it is rarely possible to kill all of the eggs, the dormant oils destroy enough to accomplish reasonable control. Such applications are regularly put on for the control of the San Jose scale and European red mite, and extra applications for the tree-hopper eggs are unnecessary. Lime-sulphur proved ineffective.

Clean cultivation is worth consideration as a last resort in cases of severe injury where the use of oil sprays is undesirable.

[13] Except *Heliria rubidella*, which feeds upon the fruit-tree twigs.

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U.S. GOVERNMENT PRINTING OFFICE: 1934

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