THE BIOLOGY OF THE WESTERN LEAF-FOOTED BUG: *LEPTOGLOSSUS CLYPEALIS* HEIDEMANN (HEMIPTERA: COREIDAE)

by

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ABSTRACT

Observations were made of a population of *Leptoglossus clypealis* Heidemann on *Thuja occidentalis* Linn. in Fresno City, Fresno County, California, in 1972, 1975, and 1976. Descriptions of the egg and five nymphal instars of *L. clypealis* are presented, together with a life history and information concerning feeding habits, courtship, copulation, oviposition, and emergence in connection with a new host, *Thuja occidentalis* Linn. Nymphs and adults were also found on a second new host, Hollywood juniper (*Juniperus chinensis torreyalosa*). Eggs and adults were seen on pomegranite (*Punica granatum* Linn.), although no nymphs were found.

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INTRODUCTION AND REVIEW OF LITERATURE

Leptoglossus clypealis Heidemann is found in California, Utah, Colorado, Arizona, New Mexico (Heidemann 1910; Essig 1958), Iowa, Kansas, and some areas of northern Mexico (Allen 1969). It is one of five *Leptoglossus* species occurring in California, the others being *phyllopus* Linnaeus, *zonatus* Dallas, *brevirostris* Barber, and *occidentalis* Heidemann, and one of ten found in the United States (Hussey 1953; Allen 1969).

The literature makes no notation of eggs or nymphs, but the adults of *L. clypealis* may be found feeding on a wide variety of hosts, such as the flowers of yucca (Essig 1958), plums and almonds (Heidemann 1910), pomegranite (Torre-Bueno 1941), and aromatic sumac, *Rhus aromatica* Ait. (Froeschner 1942). *L. clypealis* Heidemann may also be found on common yucca (*Yucca rupicola* Scheele), *Thuja orientalis* Linn. (McCullough 1969), and juniper (Hogue 1974).

Analyses were made to determine the chemical composition of the fluid elicited by the metathoracic scent glands of the adult *L. clypealis* (McCullough 1969; Aldrich and Yonke 1975), but no work has been done to determine the function of the scent in the behavior of the species.

The effects of this species on seeds are unreported, but nymphs and adults of *L. occidentalis*, a close relative, damage the seeds of douglas fir (*Pseudotsuga menziesii* Mirb.) and 11 other California conifers, including nearly all the pines and firs of commercial importance. Damage appears as a shrunken endosperm, and of 15 samples of douglas fir seed collected in 1959, 5.1 percent showed this characteristic type of injury (Koerber 1963). Using caged adults and nymphs of *L. occidentalis*, Krugman and Koerber (1969) observed as much as a 55 percent destruction of seeds held in the cones of ponderosa pine (*Pinus ponderosa* Laws). This investigation did not attempt to establish expected field losses due to *L. occidentalis*. In Florida, several studies have been made of the effects of *L. corculus* Say on seed production in various species of slash pine, including *Pinus elliotii* var. *elliotii* Engelm, *P. echinata* Mill., and *P. palustris* Mill. (DeBarr 1967, 1970; Merkel and DeBarr 1971; DeBarr et al. 1972; DeBarr and Ebel 1974; DeBarr and Kormanik 1975).

No studies of the economic importance of *L. clypealis* have been made, but Curt Ferris (Personal Communication), Farm Advisor, Fresno County, California, has observed large numbers of flying adults in almond orchards in early spring. The adults fed on and stained the meat of the immature nuts and in extreme cases caused deformation and/or abortion of the fruit. Growers in the area reported up to a 1120 kilogram per hectare increase in almond yield upon application of insecticide to control *L. clypealis*. No reproduction of the species has been seen on almonds. Dr. Ferris has also observed *L. clypealis* on pomegranite, and believes the adult causes severe damage; but because he has observed the insect only on mature, cracked fruit, he feels it is of little economic significance to this orchard crop.

Leptoglossus clypealis is often seen in Fresno County, California, and is easily collected during the spring and summer months, but little is known concerning its life history and habits, host plants, and economic importance. This study attempts to encompass these areas, particularly in connection with a new host, *Thuja occidentalis* Linn., and in addition presents a description of the nymphal stages of this species.

MATERIALS AND METHODS

Observations were made of a population of *Leptoglossus clypealis* Heidemann on *Thuja occidentalis* Linn. in Fresno City, Fresno County, California, in 1972, 1975, and 1976. In 1972, 54 observations were made from 30 June to 12 August, varying in length from 10-70 minutes. About 25 percent of the observations were made from 600-1600 hours, and the remaining 75 percent from 1600-2400 hours. Twenty observations of 15-75 minutes were made from 2 June to 1 September 1975, 5 percent of these being made from 600-1600 hours and 95 percent from 1600-2200 hours. The nine 1976 observations were 15-60 minutes long and made on an irregular basis from 27 April to 10 September, and 95 percent of these were made from 1600-2200 hours.

Each observation consisted of two parts. First, a general survey of the *L. clypealis* population was made. Moving clockwise around the tree, observations were made of the feeding, mating, and oviposition habits of the insect. Great care was taken to assure that the observations of these activities were made without disturbing the tree in any way. Second, the leaves and branches were moved to and fro, and a count was made of the number of adults and immatures present. Tape markers were affixed to the tree in close proximity to egg chains to aid in their relocation at later dates. All observations were made using the naked eye or with the aid of a 10X or 30X hand lens.

Only two observations of *L. clypealis* on pomegranite (*Punica granatum* Linn.) were made, both on afternoons in early September 1976.

Foliage on this tree was sparse, thus data were collected easily without disturbing the population.

The descriptions of the egg and immatures were made under a stereomicroscope using powers from 6X to 50X, and the photographs and photomicrographs were taken with a 35 mm camera using a 55 mm lens or a microscope adapter.

Weather data were obtained from the records of the United States Department of Commerce, National Weather Service Office, Fresno Air Terminal (LAT 36 degrees 46 minutes N; LONG 119 degrees 43 minutes W; ELEV 328 feet), Fresno, California. The data were collected at this site, which is located approximately five miles southeast of the two *Thuja* where the observations of *L. clypealis* were made.

RESULTS

Description of Life Stages

Egg

Drum or barrel-shaped; laid end to end in chains of up to eleven, rarely laid singly. Color golden-brown to ochre; operculum a raised ring.
Length 1.4-1.5 mm; width 1.15-1.2 mm; height 0.9-1.0 mm. Operculum diameter 0.6 mm (Fig. 1).

First Instar

Head longer than thorax, light brown, bearing one pair brown spines on dorsum; knob on tylus; eyes red; proboscis extending to abdomen I. Antennae reddish-brown, pubescent, equal in length to body; basal joint equal in length to third, second and terminal joints subequal. Thorax light brown with one pair brown spines dorsally. Abdomen I-VII greenish to opaque off-white sometimes pinkish, VIII-X brown; segments III-VII with red spines laterally; orange patches around dorsal abdominal glands, each with one pair dark red spines. Legs reddish-brown, pubescence in longitudinal rows.
Length 2.9-3.1 mm; width across thorax 0.6-0.7 mm (Figs. 2 and 3).

Second Instar

Head longer than thorax, reddish, bearing one pair red spines on dorsum; knob on tylus, not prominant; eyes red; proboscis extending to mid-abdomen. Antennae reddish, black pubescence, longer than body; basal joint equal in length to third, second and terminal joints subequal. Thorax brown, one pair red spines dorsally. Abdomen I-VII creamy-white dotted with red, VIII-X brown; segments I,II each with one prominant pair dark red dorsal spines; segments III-VII with dark red spines laterally; dark reddish-brown patches around dorsal abdominal glands, each with one pair dark reddish-brown spines; venter of abdomen V-VII each with one pair dark red spots. Legs brown, pubescence in longitudinal rows, with dark spots at base of each hair. Length 4.2-4.4 mm; width across thorax 0.7-0.8 mm. Abdomen may appear greenish-white (Fig. 4).

Third Instar

Head longer than thorax, light brown dotted with red, bearing one pair small red spines on dorsum; knob on tylus, not prominant;

eyes red; proboscis extending to abdomen I. Antennae creamy-white, joints one to three with apical one-sixth light brown; pubescent, hairs with dark areas at bases; shorter than body; basal joint equal to or slightly shorter in length to third, second and terminal joints subequal. Thorax light brown dotted with red; one pair red spines dorsally; wing pads just evident. Abdomen I-VII creamy-white dotted with red, VIII-X brown; segments I,II each with one pair dark red dorsal spines; segments I-V with dark red lateral spots, VI-VII with dark red lateral spines; dark reddish-brown patches around dorsal abdominal glands, each with one pair dark reddish-brown spines; venter of abdomen V-VII each with one pair dark red spots. Legs brown, pubescence in longitudinal rows, with dark spots at base of each hair.
Length 6.5-6.8 mm; width across thorax 1.1-1.2 mm. Color pattern constant, may be lighter or darker (Fig. 5).

Fourth Instar

Head shorter than thorax, light brown dotted with red, bearing one pair small spines dark at apex on dorsum; knob on tylus, not prominant; eyes red; proboscis extending to abdomen I. Antennae creamy-white, basal joint dotted with red entirely, joints two and three dotted with red, intensely at distal ends; dark pubescence, no dark areas at bases of hairs; shorter than body; basal joint equal in length or slightly shorter than third, second and terminal joints subequal. Thorax light brown dotted with red; one pair spines, dark at apex, on pronotum; wing pads cover abdomen I, dark brown at distal ends. Abdomen I-VII creamy-white dotted with red, VIII-X brown; segments I,II each with one pair dark dorsal spines, reduced in size; segments I-VI with dark red lateral spots, VII with dark red lateral spines; dark reddish-brown patches around dorsal abdominal glands, each with one pair dark knobs; venter of abdomen V-VII each with one pair dark red spots. Legs light brown, dotted with red and brown; pubescent; metatibia beginning to flatten.
Length 10.7-11.0 mm; width across thorax 2.1-2.2 mm. Color pattern constant, may be lighter or darker (Fig. 6).

Fifth Instar

Head shorter than thorax, light brown dotted with red; spine on tylus acute; eyes red; proboscis extending to abdomen I. Antennae creamy-white, basal segment dotted with red entirely, segments two and three dotted with red, intensely at distal ends; dark pubescence; shorter than body; basal joint equal in length or slightly shorter than third, second and terminal joints subequal. Thorax light brown dotted with red; one pair reduced dark spines on pronotum; wing pads cover abdominal I-III, dark brown at distal ends. Abdomen entirely light brown dotted with red; segments I,II each with one pair dark dorsal spines, reduced in size; segments I-VII with dark red lateral spots; dark reddish-brown patches around dorsal abdominal glands, each with one pair dark knobs. Legs creamy-white to brown,

dotted with red; pubescent; metatibia flattened; hind femora armed with a double row of black spines beneath.
Length 12.7-13.1 mm; width across thorax 4.0-4.2 mm. Color pattern constant, may be lighter or darker (Fig. 7).

Adult

Body oblong, light brown to tan, with golden brown pubescence. White zigzag fascia, transverse across corium of hemilytra. Metatibia flattened and expanded into a spatulate-shaped plate. Heidemann (1910) in his detailed description of the adult, and Allen (1969) indicate that *clypealis* can be distinguished from all other known *Leptoglossus* species by the acute spine on the tylus (Fig. 8) and the pale membrane of the hemilytra.
Length 18-21 mm; width across thorax 6-8 mm (Fig. 9).

Hosts and Feeding Habits

L. clypealis was observed feeding on the cultivated Arborvitae *Thuja occidentalis* Linn. (Fig. 10), pomegranite, and Hollywood juniper. On *T. occidentalis*, *L. clypealis* fed on the leaves, primary stems, and whitish bloom-covered immature cones. The last were the most common feeding site; about 100 adults of this species were noted feeding on them during the course of the 1972 and 1975 observations. Only four sightings of adults feeding on the stems and leaves were made during the same period. All immature stages of the insect, except the first instar nymph, were seen to penetrate and feed on cones 6-7 mm (early May) to 10-13 mm (mid-July on) in diameter. Instar I was only observed feeding on the leaves, but whether this was the exclusive food source for it is not known. *L. clypealis* was seen to penetrate and feed on all areas of the cone, showing no preference for one region over another.

The feeding process on the immature cones of *T. occidentalis* began with a probing of the cone by the insect's proboscis. The antennae were also lowered until they contacted the cone, and were perhaps used as sensory organs. While probing, a slight backward bend occurred between labial segments two and three, and upon selection of a penetration site, the protarsi were placed close together on the cone. The proboscis became rigid at a 90 degree angle to the plane of the insect's body, and the stylets entered the cone at a point between the protarsi. In seconds, the basal segment of the labial sheath folded flat against the venter of the head (Fig. 11), segment two angled downward to segments three and four, which still ensheathed the stylets. This was the most common feeding posture observed on the cones of *T. occidentalis*, and was usually accompanied by a "bobbing" motion of the insect as it moved its stylets up and down within the cone. On one occasion, however, the entire labial sheath was seen held flat against the venter of the insect, and the stylets were completely buried in the flesh of the cone.

Three feedings were observed from initiation to completion, and took 7, 12, and 30 minutes respectively. Three other feedings, in progress before beginning to record their time, took 10+, 15+, and 15+ minutes. Most feedings were believed to fall well within the range of 7-30 minutes.

Feeding terminated suddenly in response to sufficient disturbance, or for no apparent reason (perhaps the feeding was completed). The stylets were withdrawn, aided in all cases by a pushing of the prothoracic legs, and held at a 90 degree angle to the plane of the body. The labium re-ensheathed the stylets, and the proboscis was returned to its resting position against the venter of the insect. A drop of clear liquid was left at the point of penetration as the only immediately noticeable surface evidence that the cone had ever been fed upon. Within 24 hours, however, a dark spot clearly marked the feeding site.

The stylets of *L. clypealis* appeared to just enter the tissue when feeding on stems of *T. occidentalis* and penetration was shallow compared to that which was observed on cones. This method of feeding was seen in the case of four individuals, and involved no "bobbing" as was noted on the immature cones.

Only adults of *L. clypealis* were seen on pomegranite. Unlike the observations of Ferris (Personal Communication), the bugs were not found on mature, cracked fruits, but were present and fed on developing fruits (Fig. 12) and were also observed moving about the leaves and branches. On 28 August 1976, 50-60 adults were observed feeding, and without making an actual count, most of those observed had all four labial segments flattened against their venter, and the complete length of their stylets buried in the fruit. As with *Thuja*, *L. clypealis* showed no favoritism for one area of the pomegranite fruit over another; but unlike *Thuja*, where only one individual was observed per cone, as many as five individuals were observed feeding on a single 8 cm diameter immature fruit at one time. No data were collected on lengths of feeding times on pomegranite.

Other than noting that adults and nymphs of *L. clypealis* fed on the leaves, stems, and cones of Hollywood juniper, no other data was recorded about the insect on this host.

Courtship, Copulation, and Oviposition on *Thuja occidentalis*

Observations of these activities were made on two *T. occidentalis* trees located in the yard of a private residence in Fresno City, Fresno

Whether pheromones were used to initiate courtship and draw the sexes together was not known. On one occasion a female of the species was observed contracting her abdomen in rapid succession. Two males within 30 cm of the female suddenly moved in her direction. An attempt was made to mount the female by each of the males, but neither was successful, and she moved away from both when physical contact was made.

The initiation of the act of copulation was observed on three separate occasions. In each case, the male was observed to approach the female straightfoward from the rear. He rapidly climbed onto the female's back, and within 2 minutes had lowered his aedeagus and inserted it into her. After linkage, the male rotated 180 degrees laterally until the two insects were posterior to posterior. This was the common mating position and was observed 41 times over the three summers that observations were made. The length of copulation time was never clearly established. The longest time recorded was 50 minutes, but copulation was already in progress when the time was noted. Natural, undisturbed termination of the sex act was never observed. However, with disturbance, the male removed his aedeagus from the female, retracted it into his body, and walked off. Feeding by one or both members of a copulating pair was not common, but was observed in two cases, and copulation appeared to progress unhampered. On one occasion a second male attempted to mount a female already copulating with another male. The pair moved away, rendering the attempt unsuccessful.

Egg chains were found laid along both the upper and lower surfaces of the stems bearing the scale-like leaves (leaf stems), lengthwise along the primary stems, and on the cones. As 26 observations were made of egg chains on cones, they were the most popular oviposition site. In comparison, six chains were found on leaf stems and two chains on primary stems. On cones, up to three egg chains were seen laid side by side, but along leaf stems and primary stems, only single chains were observed.

A female was observed placing her antennae on either side of a leaf stem. She then moved to a second leaf stem and repeated the process, after which she began to oviposit on the leaves of the second leaf stem. It appeared that the only difference between the two leaf stems was that the leaves of the second were slightly wider than those of the first. No observations were made of the behavior of the female prior to ovipositing on a primary stem or cone.

When a leaf stem or primary stem was the oviposition site, the female aligned her body parallel to the leaf stem or the primary stem itself, and laid her eggs along it. Of the eggs that were laid on cones, no repetitive pattern was established, and egg chains were found deposited in many different directions and on all areas of the cone's surface. The actual process of depositing the eggs was observed four times and was the same on all of the above mentioned substrates. The female lowered her posterior to within an estimated 0.5 mm of the surface and extended and retracted her ovipositor several times over 15-30 seconds touching the substrate on the rearward stroke, and clearing it on the return motion. The area touched by the ovipositor on its rearward stroke appeared to be somewhat "cleaned" by the action. This was particularly noticeable on the cones, where some of the white bloom was rubbed off. In addition, some sort of "cement" or "glue" appeared to have been applied to the area cleaned. With a sudden greater contraction, an egg was extruded, set into place, and held there a few seconds by the ovipositor. The female then moved forward about one egg length and repeated the process at the rate of one egg every 40-60 seconds, for a total of up to 11 eggs per chain.

Emergence and Molting on *Thuja occidentalis*

One observation of the emergence of the first instar *L. clypealis* was made. The operculum of the egg ruptured, and the nymph emerged head first with the metathoracic legs being withdrawn lastly.

Many of the eggs observed (the exact number or percentage of the total out of all eggs observed was unknown) showed an emergence hole on the side, while the operculum remained intact. Five unhatched *L. clypealis* eggs were collected and placed in a jar for 8 days. On the eighth day, five parasitic wasps of the genus *Ooencyrtus* Ashmead (Hymenoptera:Encyrtidae) emerged from a rupture in the side of one egg.

Molting was observed on one occasion: from nymphal instar I to II. Ecdysis began with a splitting of the old cuticle along the ecdysial lines. The anterior half of the exuvia was shed first, followed by that portion which encased the abdomen and metathoracic legs. The exuvia seemed to be caught on a leaf, and the nymph merely walked down the branch, pulling itself out of its old "skin." The newly emerged nymph appeared white to pinkish in color with red areas surrounding the dorsal abdominal glands.

Occurrence on *Thuja occidentalis*

In 1976, an observation was made of the two *T. occidentalis* trees under study on 27 April, and no adult *L. clypealis* were seen. A second observation was made on 10 May, and five adult males were found. Females were seen within 2 weeks, and egg chains appeared 3 June.

The two trees were again inspected on 30 August 1976, and adults were present. However, when the trees were observed on 14 September and thereafter, no adults were found.

Visual counts were made of the numbers of *L. clypealis* seen on the easternmost of the two *T. occidentalis* trees in 1972 and 1975. Summaries of these data are found in Tables 1 and 2 and Figs. 13 and 14.

The numbers indicated in Table 1 were believed to constitute an absolute count of the insects present. However, because of the mobility of *L. clypealis*, some individuals may have been counted more than once, and some, hidden in the foliage, may have escaped the count entirely. Thus no valid statistical analyses can be performed, and the data may be used to show trends only.

By 1975, the *T. occidentalis* tree had grown too large to permit an absolute count to be made. Samples were taken, but no standardized method of sampling was devised, and therefore, this data (Table 2) also was useful only for trend purposes.

Miscellaneous Habits

L. clypealis were seen from early May to early September on the cultivated Arborvitae *Thuja occidentalis*, wandering about the foliage

TABLE 1 1972 DATA - *LEPTOGLOSSUS CLYPEALIS* HEIDEMANN - EAST TREE

Date 1972	Time of Observation	Elapsed Time (min)	*L. clypealis* population*				Weather Data**		
			Adult	Instar V	Instar IV	Instars I-III	Max. Temp. (°F)	Rain-fall (in)	Avg. Windspeed (mph)
7-6	1835-1850	15	11	-	-	-	98	0	7.8
7	2000-2030	30	16	-	-	-	98	0	9.2
8	1955-2010	15	1	-	-	-	94	0	6.6
9	2000-2030	30	11	-	-	-	99	0	8.5
11	2020-2050	30	9	-	-	4	101	0	6.8
12	***	***	3	-	-	4	105	0	7.3
15	1930-2020	50	10	-	-	-	111	0	8.9
16	1945-2000	15	15	6	5	15	101	0	7.8
17	2000-2015	15	10	8	-	-	97	0	8.1
19	2000-2030	30	6	6	4	12	90	0	10.6
20	1930-1950	20	5	5	6	16	82	0	9.8
22	1950-2030	40	9	27	-	12	92	0	8.5
23	***	***	19	12	11	22	95	0	7.6
25	2000-2030	30	32	9	7	11	97	0	7.1
27	1945-2005	20	59	24	10	11	99	0	7.6
31	1930-2000	30	52	15	2	2	101	0	8.8
8-2	1945-2010	25	35	18	5	6	96	0	6.6
4	1900-1930	30	33	24	6	2	99	0	7.5
5	1945-2015	30	35	20	4	3	105	0	6.8
6	1930-1950	20	19	12	3	2	103	0	7.6
7	1930-1950	20	22	9	5	1	104	0	7.2
8	2000-2015	15	22	8	1	-	102	0	6.6
9	1930-1955	25	23	13	1	2	102	0	7.5
12	1730-1750	20	7	4	-	3	96	0	9.2

* Data may be used to show trends only, since absolute counts may be inaccurate (see text).

** Courtesy U. S. Dept. of Commerce, National Weather Service Office, Fresno Air Terminal (LAT 36° 46' N; LONG 119° 43' W; ELEV 328'), Fresno, California.

*** No time of observation recorded.

\- No data available.

TABLE 2 1975 DATA - *LEPTOGLOSSUS CLYPEALIS* HEIDEMANN - EAST TREE

Date 1972	Time of Observation	Elapsed Time (min)	*L. clypealis* population* Adult	Instar V	Instar IV	Instars I-III	Weather Data** Max. Temp. (°F)	Rain-fall (in)	Avg. Windspeed (mph)
6-2	1400-1430	30	5	0	0	0	89	0	6.6
9	1925-2040	75	6	0	0	0	99	0	5.3
13	1935-2020	45	3	1	0	3	101	0	5.5
16	1900-1930	30	0	0	0	0	92	0	8.9
18	1905-1955	50	1	1	2	1	79	0	6.8
26	1920-2020	60	7	1	1	1	88	0	5.5
7-1	1900-1930	30	1	1	2	3	85	0	7.5
7	1900-2005	65	15	1	1	0	96	0	7.3
11	1900-1950	50	23	0	0	0	100	0	5.8
16	1905-1940	35	22	3	0	1	88	0	6.2
21	1905-1955	50	20	0	0	0	95	0	6.2
23	1905-1940	35	20	0	0	2	102	0	6.0
8-4	1905-2005	60	12	6	1	9	103	0	5.3
11	1700-1725	25	2	3	0	1	98	0	5.5
25	1840-1900	20	13	1	1	1	98	0	5.9
9-16	1615-1630	15	0	1	0	0	91	0	4.3

* Data may be used to show trends only, since no standardized sampling method was used.

** Courtesy U. S. Dept. of Commerce, National Weather Service Office, Fresno Air Terminal (LAT 36° 46' N; LONG 119° 43' W; ELEV 328'), Fresno, California.

or simply resting there. Neither adults nor nymphs were found to show great response to an occasional mild disturbance. However, upon persistent disturbance, such as continued movement of the leaves and branches, either manually or by naturally occurring wind, they moved down the leaves and stems to the dense foliage of the center of the tree. The adults are strong flyers and may take to the air when disturbed producing a loud buzzing sound strongly reminiscent of a bumble bee.

DISCUSSION

Koerber (1963), in his studies of *Leptoglossus occidentalis* on douglas fir, described many feeding habits similar to those observed for *L. clypealis* on *T. occidentalis*. The target of penetration and feeding by *L. occidentalis* was found to be the endosperm of the seeds held within the cone of douglas fir. In the field, the mouthparts of *L. occidentalis* were seen to penetrate the cone at a point between the protarsi which were placed close together on the cone's surface. The complete length of the stylets was then pushed through the cone's scales to the seeds, and the entire labium was held flat against the venter of the insect. In laboratory studies of *L. occidentalis*, using seeds which were previously removed from the cone, Koerber observed that the labium was bent at the basal joint, and that only the two basal segments were folded flat against the venter of the insect. This suggests the possibility that the position assumed by the labium might be directly correlated with the depth the stylets must penetrate to reach the endosperm of the seed. In the field, the seeds were held within the cone, and full penetration was necessary to reach the endosperm. Thus the entire length of the labium was folded to the venter of the insect. In the laboratory, however, the seeds were free from the cone, and the stylets did not have to penetrate as far to the endosperm. Therefore, a folding of the entire labium was not necessary and did not occur.

Studies of *L. occidentalis* (Koerber 1963) and *L. corculus* (DeBarr 1967, 1970; Merkel and DeBarr 1971; DeBarr et al. 1972; DeBarr and Ebel 1974; DeBarr and Kormanik 1975) noted that the endosperm of the seed was the target food source for these species. The same seems to be likely for *L. clypealis*.

The same two positions of the labium that Koerber (1963) described for *L. occidentalis* were also seen in *L. clypealis*. The partial penetration of the stylets accompanied by a folding of but one labial segment against the venter was seen in all but one of the cases where *L. clypealis* fed on *T. occidentalis* cones, possibly indicating that total penetration was not necessary to reach the endosperm in most cases. That case in which complete penetration of the stylets occurred might have been due to an oversize cone, or improper angle of penetration resulting in a greater distance from surface of cone to endosperm. The entire length of the stylets was pushed into pomegranite in all cases where *L. clypealis* was observed feeding on that host, perhaps indicating that the distance from surface to seed is greater in pomegranite than in *T. occidentalis*. If, however, the preceding statement is true, a question might be raised as to how it is possible for the nymphs to feed on the seeds held within the developing fruit. No complete answer can be given to this question, because the first observation of *L. clypealis* on pomegranite was not made until 28 August 1976. On this date, eight eclosed eggs were found on an immature fruit, but no nymphs were seen. The presence of eclosed eggs would seem to indicate that nymphs were at one time present, but it is not known how or on what part of the pomegranite tree they fed. The presence of adults only might be an indication that the immatures had completed metamorphosis by this date, or not being able to feed, the nymphs died shortly after eclosion. Late summer migration to pomegranite from another host might also serve as an explanation of why only adults were found. Such migration was seen to occur on almonds in early spring (Ferris, Personal Communication).

Koerber (1963) stated that *L. occidentalis* injects saliva into the seeds of douglas fir via the stylets. The endosperm is dissolved, and the liquified material is moved to the insect's gut by imbibition. The same process may occur in *L. clypealis*. Since only four observations were made of stem feeding, it may be that stems do not play a vital role in the total nutrition of *L. clypealis*.

The courtship and copulation habits have not been described for any of the close relatives of *L. clypealis*. Oviposition and emergence, however, have been described for *L. occidentalis* on douglas fir (Koerber 1963), and observations of these activities were similar to those made for *L. clypealis*. The eggs of both *L. occidentalis* and *L. clypealis* were deposited end to end in chains, but the former oviposited mostly on needles while the latter preferred cones. Both species secured their eggs to the substrate with a drop of "glue." Emergence was the same for both species. The operculum ruptured and the nymph emerged through it, leaving the remainder of the chorion intact.

The population data accumulated in 1972 and 1975 (Tables 1 and 2; Figs. 13 and 14) show some trends. Analysis of these data together with the data collected in 1976 on seasonal arrival and departure times allows a generalized life history to be outlined. The overwintered adult males of *Leptoglossus clypealis* arrived at the host *Thuja occidentalis* tree about the first week of May. The females arrived within 2 weeks and oviposition began. The adult population built slowly as a new generation (I) developed from eggs deposited by the colonizing generation. Ten to 12 weeks after the overwintered adults arrived, the adult population exhibited rapid growth as the metamorphosis of generation I neared completion. The adult population remained at this level for no longer than 1 week, and then experienced a rapid die-off. Generation I adults had meanwhile mated, and the eggs laid by these new adults, as well as those laid by survivors of the colonizing generation, accounted for a new build up of developing nymphs. This led to a second build up of adults, not as great in number as the first, about one month later (generation II). As the month of September neared, the number of adults and nymphs began to dwindle. The nymphs were reduced in number as they completed metamorphosis or died, and the adults were either dispersing as part of a diapause period or, unlikely, dying off.

Through the season many fluctuations occurred in the numbers of individuals observed (Figs. 13 and 14). Many of these fluctuations might be explained by the weather data (Tables 1 and 2). Temperature, while affecting the developmental times (e.g., the differences in developmental times of generations I and II), probably did not have any effect on day-to-day population levels of the adults. Wind movement caused the leaves and branches of *Thuja* to be set into motion, and this disturbance, while a natural occurrence, caused the insects to migrate toward the center of the tree. Hidden in the foliage, *L. clypealis* were difficult to find, and while actual numbers of these insects may not have changed, the numbers tallied were lower.

The economic significance of *Leptoglossus clypealis* to *Thuja occidentalis* cannot be assessed based on this study. If indeed this species does feed on the endosperm of the seeds, a reduction in seed germination might be expected; but as this host is used primarily as an ornamental, it is doubtful that a lower percentage of seed viability would be economically important. The damage that adults apparently inflict upon developing almonds might be of great economic importance. Indeed, the production differences between treated and untreated plots (Ferris, Personal Communication) in Fresno County, California, suggest that a problem exists with this species on almonds. Ferris tended to discount the importance of *L. clypealis* on pomegranite since he observed feeding adults only on mature, cracked fruit. That the species was seen on immature fruit in this study might indicate that a problem could exist.

While *L. clypealis* is apparently native to this area of the world, the species has yet to be recorded on an indigenous host. Numerous plant species have been introduced into this insect's geographic range, and some have apparently replaced endemic species as favored hosts, as indicated by the absence of observations of *L. clypealis* on native vegetation. That complete host transfer has taken place would seem unlikely, however, since few native arboreals have become extinct as a result of man's encroachment and his introduction of competing plant species. Perhaps *L. clypealis* occurs on native vegetation only when the favored, introduced hosts are not available.

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APPENDIX

FIGURES

Fig. 1. Drum-shaped eggs of *Leptoglossus clypealis* Heidemann on an immature *Thuja occidentalis* cone. Some of these eggs have hatched normally, others show the side rupture of an emerged parasite. 3.5X life size.

Fig. 2. Comparison photograph of the five nymphal instars of *Leptoglossus clypealis* Heidemann, showing size relationships. Preserved specimens. 3X life size.

1

2

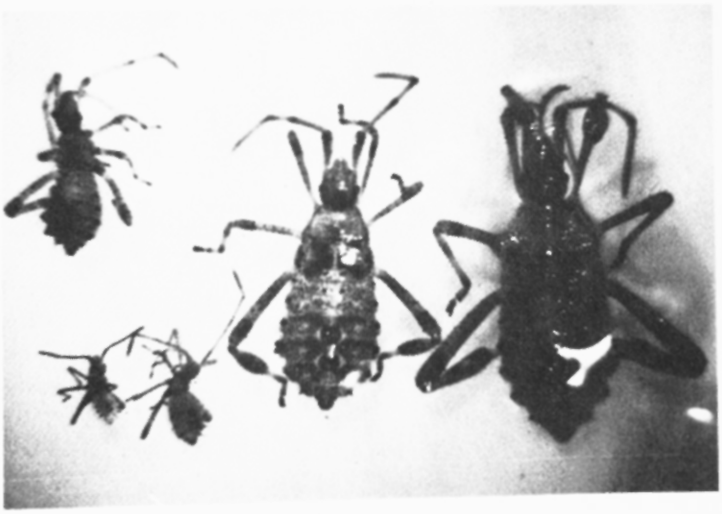

Fig. 3. First instar nymph of *Leptoglossus clypealis* Heidemann. Preserved specimen. 13.5X life size.

Fig. 4. Second instar nymph of *Leptoglossus clypealis* Heidemann. Preserved specimen. 8.5X life size.

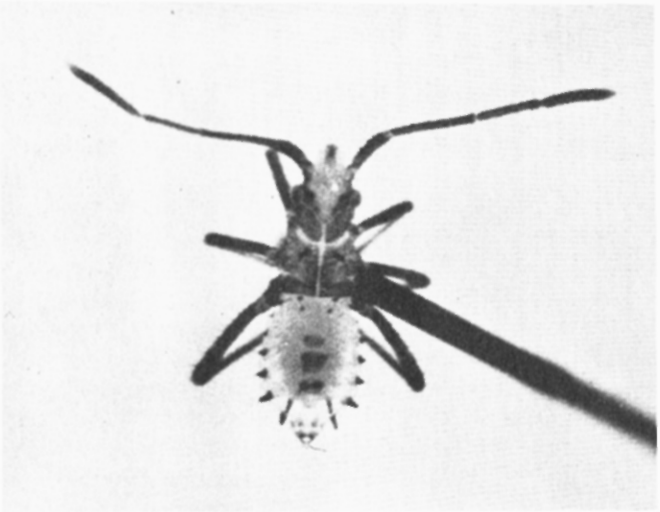

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Fig. 5. Third instar nymph of *Leptoglossus clypealis* Heidemann. Preserved specimen. 9X life size.

Fig. 6. Fourth instar nymph of *Leptoglossus clypealis* Heidemann. Preserved specimen. 5X life size.

Fig. 7. Fifth instar nymph of *Leptoglossus clypealis* Heidemann. Preserved specimen. 5X life size.

Fig. 8. Head of *Leptoglossus clypealis* Heidemann showing acute spine projecting from the tylus. Pinned specimen. 8.5X life size.

5 6

7 8

Fig. 9. Adult of *Leptoglossus clypealis* Heidemann. Pinned specimen. 2.5X life size.

Fig. 10. *Thuja occidentalis* tree where observations were made of *Leptoglossus clypealis* Heidemann population.

Fig. 11. *Leptoglossus clypealis* Heidemann feeding on immature cones of *Thuja occidentalis*. Note stylets and folding of labial segments one and two. 1.5X life size.

Fig. 12. *Leptoglossus clypealis* Heidemann on the developing fruit of pomegranite. Life size.

9 | 10
11 | 12

FIGURE 13

1972 Population of L. clypealis

Host: T. occidentalis

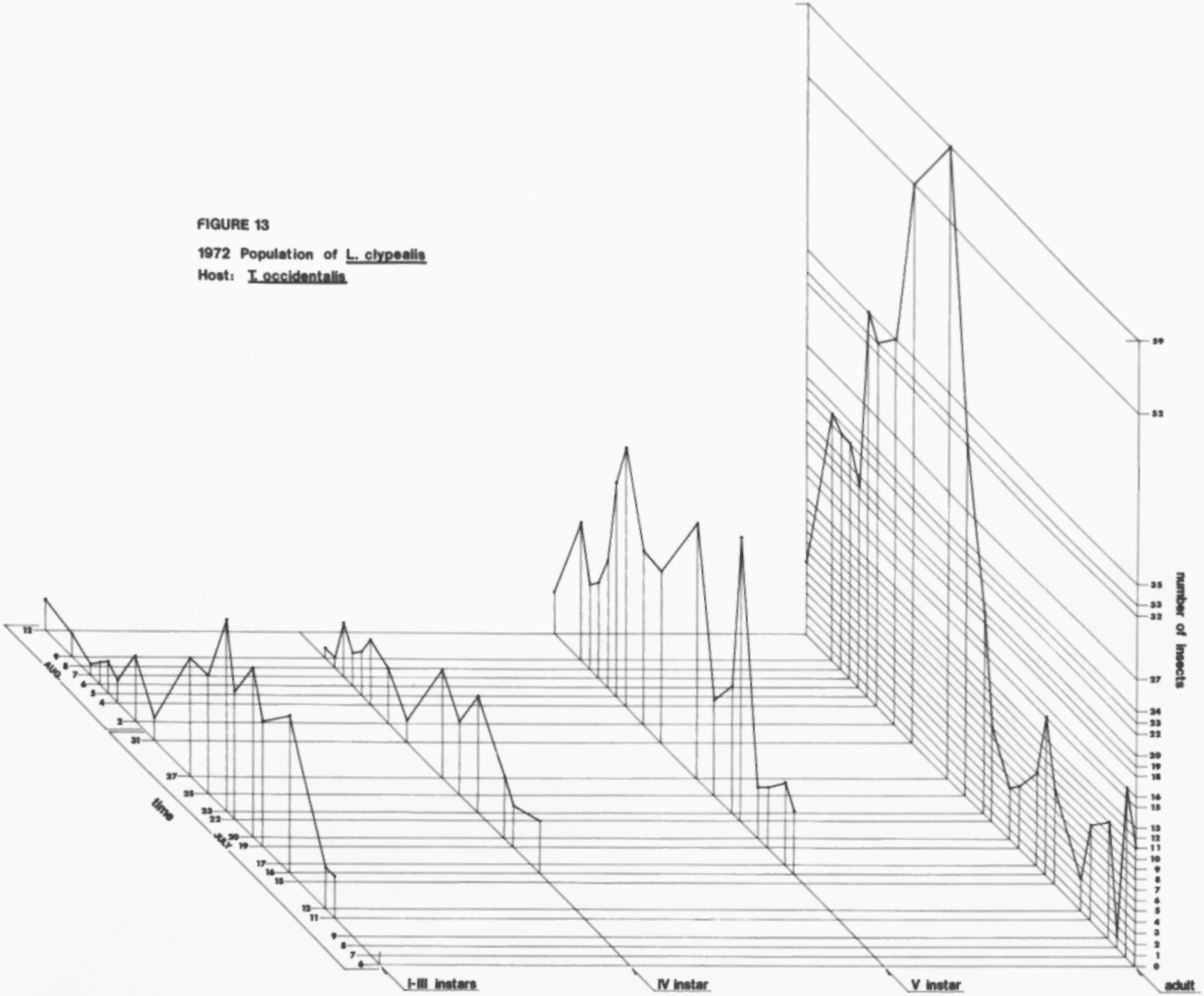

FIGURE 14

1975 Population of L. clypealis
Host: T. occidentalis