# SOME ECOLOGICAL STUDIES ON THE TWICE-STABBED LADY BEETLE CHILOCORUS STIGMA (SAY) [1]

MARTIN H. MUMA, Associate Entomologist, Florida Citrus Experiment Station, Lake Alfred

The most common large lady beetle associated with citrus in Florida is *Chilocorus stigma* (Say), the twice-stabbed lady beetle (Watson, 1918). Although the species is an omnivorous feeder, large populations are more frequently found in groves infested with Florida red scale, *Chrysomphalus aonidum* (L.). Such occurrence indicates that the beetle may be an important factor in minimizing damage by this scale, which is of major importance on citrus in the state.

To obtain more detailed information on the twice-stabbed lady beetle and to establish its importance as a scale predator, several studies were initiated. They included identification in all stages of development, investigation of the general biology under grove conditions and controlled experiments on the life cycle, longevity, food preference, food consumption and fecundity of the species.

## METHODS AND MATERIALS

Nine groves distributed in the northern, central and western citrus growing areas of the state were utilized for the observations and experiments reported here. Special collections were also made in one grove on the East Coast. Estimations of populations were based on the number of adult beetles observed on a tree during a five minute interval. Counts were replicated four times on four different trees. Estimations of scale populations were based on the number of leaves in a randomly picked 50 leaf sample with at least one living female scale.

Descriptions were made from laboratory-reared specimens. Biological observations and tests were made on both laboratory reared and newly moulted or emerged grove specimens.

In the laboratory experiments, eggs were handled in cotton-stoppered homeopathic vials, early instar larvae in test tubes and late instar larvae and adults in petri dishes. Life cycle and special food studies were conducted in constant temperature chambers thermostatically controlled to a four-degree range. A mean summer temperature of 80° F. was maintained for all except the life cycle studies. In the latter a twenty-year mean of 80° F. was computed and used for the summer and 62° F. for the winter with 70° F. arbitrarily chosen for spring and fall temperatures.

A special chamber was utilized for food preference studies in the laboratory. The chamber measured 2.0″ x 4.5″ x 10.5″ with a clear plastic top, wooden ventilated walls, an inner floor of aluminum having twelve ¾″ bevel-edged-holes arranged in two rows and a solid outer floor of aluminum. Test materials were placed over the holes on the inner floor and held in place by the outer floor.

## IDENTIFICATION

As review of the literature indicated a possible confusion of two or more species under the name *Chilocorus stigma* (Say) (= *bivulnerus* Muls.) the following descriptions are given to identify the species utilized in this study.

The eggs of the twice-stabbed lady beetle are elongate oval and measure about 1.1 mm. long and 0.5 mm. wide (Fig. 1). This shape and size approximates that previously reported, (Girault, 1907). When first laid the eggs are light lemon yellow but soon darken to orange and just prior to hatching turn dark brown to silvery grey. The orange coloration was noted earlier by Girault (1907) and the brown by Fiske (1903).

Descriptions of larvae, pupae and adults have been published by Watson (1918) and although rather general they agree with those given below. The figure of the adult included by Watson, however, is not the twice-stabbed lady beetle but the southern two-spotted lady beetle, *Olla abdominalis* var. *plagiata* Say.

Newly hatched or moulted larvae are light tan but soon darken to brown, grey or almost black. The entire dorsum is covered with prominent senti, 10 on the prothorax, 8 on the mesothorax and 6 on the metathorax and on each abdominal segment except the last which has only four. First instar larvae are uniformly colored but later instars have the dorsal midline of the thoracic and abdominal regions and much of the dorsum of the first abdominal segment light cream to white (Fig. 3). Fully fed specimens have a rosy tint. First instar larvae measure about 1.0 mm. in length whereas fourth instar larvae are about 6.0 mm. long.

Pupation takes place within the last larval exuviae with new pupae a light lemon yellow and old pupae dark brown, grey or black. Pupae are marked much like late instar larvae except that the abdominal marking is yellow to orange and has a tendency to be interrupted, forming two distinct spots. The pupae are about 5.0 mm. long.

Newly emerged adults are a light cream color with a pair of small pink to light orange spots occurring near the middle of the elytra. Shortly after emergence the beetles turn dark brown to

[1] Florida Agricultural Experiment Station Journal Series, No. 278.

Date of acceptance, June 25, 1954.

black and the elytral spots become red (Fig. 2). The venter remains a light yellow, except for the thoracic sternites which are dark brown to black. Males and females are similarly marked and except for size are difficult to distinguish; the former measure 3.5 to 4.0 mm. whereas the latter average from 4.0 to 5.0 mm.

## GENERAL BIOLOGY

The twice-stabbed lady beetle undergoes seven stages of development: egg, four larval instars, pupa and adult. Several generations are produced each year. Beetle populations are lowest in the late summer, fall and early winter, increase gradually during the late winter and early spring and reach a peak in the late spring and early summer (Fig. 6). Exceptions to this life history occur in certain sprayed groves and possibly were responsible for the late winter populations reported by Mathis (1947). Causes for these exceptions have not been investigated.

Adults and larvae both are voracious and omnivorous feeders. The species has been recorded feeding on various scales, (Sasscer, 1912; Caesar, 1914; Turner, 1914; Watson, 1914; Nakayama, 1915; Simanton, 1916; Fenton, 1917; Roullard, 1917; Herbert, 1920; Essig, 1920 and Mathis 1947) several species of aphids (Davis, 1915; Lauderdale, 1921; Smulyan, 1921 and Beyer, 1924) and mealybugs (Essig, 1914). In the present study on citrus, the species has been observed eating Florida red scale, purple scale, *Lephidosaphes beckii* (Glover), chaff scale, *Parlatoria pergandii* Comst., long scale, *Lepidosaphes gloverii* (Pack.), soft brown scale, *Coccus hesperidum* L., citrus mealybug, *Pseudococcus citri* (Risso) and green citrus aphid, *Aphis spiraecola* Patch. Adult beetles and all stages of larvae feed on the larger scales. Although the species has been reported to feed on eggs and crawlers (Watson, 1918 and Griffiths and Thompson, 1949) it does not eat these two forms in significant quantities.

Eggs are laid singly or in groups of two, three or four on their sides as reported by Girault (1907). Smith (1897) who reported deposition on end in little groups apparently confused the twice-stabbed lady beetle with another species, possibly the southern two-spotted lady beetle. Deposition of eggs has been reported in crevices of the bark (Girault, 1907) and under scale armors (Marlott, 1902) on leaves and trunks of trees infested with scale (Glover, 1859 and Fiske, 1903). In the present study eggs have also been found under sooty mold and other litter on scaly leaves, fruit and twigs. Larvae feed on all parts of the tree but when mature move to dead twigs and the under sides of large limbs where they pupate. Mature larvae seem to be gregarious, as large clusters of pupae are found at these sites in the late spring and summer (Fig. 4). After feeding for a short period of time, newly emerged adults mate and the females soon begin laying eggs.

Adult activity is more variable than that of larvae. Beetles are more numerous on the tree trunks and limbs in the late summer, fall and early winter but prefer feeding on the leaves and fruit in late winter, spring and early summer. During rain storms adults seem to disappear from the trees.

Entomogenous fungi, such as *Beauveria bassiana* (Bals.) Vuill and *Fusarium sambucinum* Fuckel, cause large mortalities of larvae and adults respectively in July and August, during the rainy season (Figs. 5 and 6). All attempts to rear insect parasites from the eggs, larvae, pupae and adult beetles have failed.

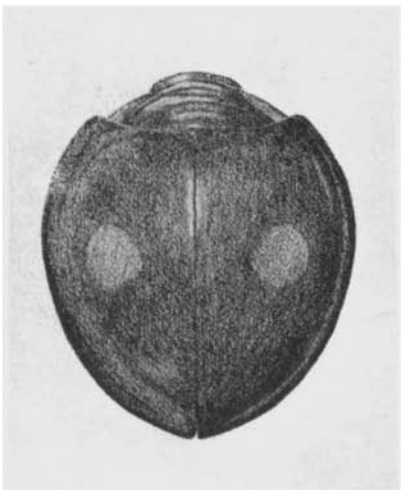
## LIFE CYCLE

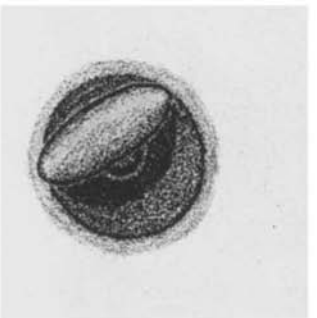
Life cycle studies were conducted principally in the laboratory under controlled conditions.

Adults were collected from groves and maintained at 80° F., 70° F. and 62° F. Eggs were laid rapidly at 80° F. and 70° F. but not at 62°F. Consequently to start life cycles at 62° F., eggs laid at 80° F. were used; life cycles at 80° F. and 70° F. were started with eggs laid at these temperatures.

Of the 582 eggs obtained at 80°F. and 70° F., 67.2% were laid singly, 25.8% as twins, 5.7% as triplets and 1.4% as quadruplets. No appreciable variation from these percentages was noted for the two different temperatures. Altogether 236 eggs were incubated at 80° F., 111 at 70° F. and 235 at 62° F. Cannibalism of unhatched, multiply laid eggs was 2.1% at 80° F., 2.7% at 70° F., and 1.3% at 62° F. Only 14.4% of the eggs failed to hatch at 80° F. and 70° F. and 6.8% at 62° F. The mean incubation period at 80° F. was 7.28 days with a minimum of 2 and a maximum of 9; at 70° F. 12.60 days with a minimum of 3 and a maximum of 15; at 62° F. 18.07 days with a minimum of 9 and a maximum of 25. Eggs incubated at 80° F. developed at nearly three times the rate of those incubated at 62° F. but suffered a higher mortality.

An arbitrary number of larvae hatched at the three different temperatures were maintained at those temperatures on a diet of Florida red scale. Larval and pupal developmental periods obtained from these cultures are presented in Table 1. Larvae maintained at 80° F. completed development and emerged as adults in about 4 weeks; those at 70° F. in about 6 weeks; those at 62° F. in about 12 weeks. From the data presented it appears that first and fourth instar larvae are more susceptible to mortality than other instars or pupae. Low temperature seems to be more hazardous to developing larvae than high temperature. Pupae were generally less variable in developmental time and less susceptible to mortality than larvae.





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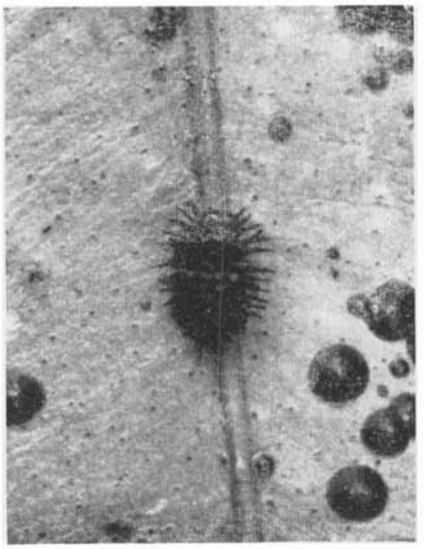

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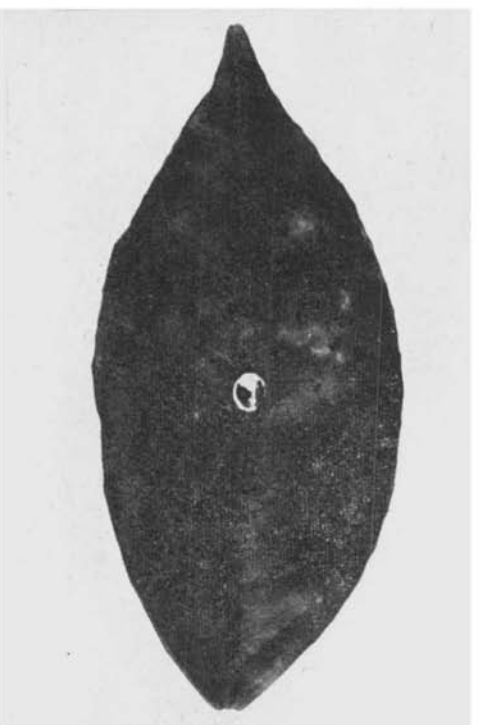

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FIG. 1. Egg of twice-stabbed lady beetle, *Chilocorus stigma* (Say), under armor of Florida red scale, *Chrysomphalus aonidum* (L.).
FIG. 2. Adult beetle.
FIG. 3. Third instar larva on citrus leaf infested with Florida red scale.
FIG. 4. Cluster of pupae on dead citrus twig.
FIG. 5. Adult beetle exhibiting mycelial development of *Fusarium sambucinum* Fuckel, a parasitic fungus.

Counts were made in nine groves distributed in the northern, central and western citrus growing areas of the state to determine monthly and seasonal variations in populations of adult beetles. Figure 6 shows the seasonal variation in population of beetles from August, 1952 to December, 1953. The trend line followed that expected from the laboratory life cycle studies with a peak occurring in the spring and summer, and a depression in the fall and winter.

### LONGEVITY

Laboratory studies on longevity were conducted on first and fourth instar larvae and adults. Tests were run under starvation and fully fed conditions. Table II presents the resultant data. Larvae lived nearly as long when starved as when completing a stadium, indicating a rather strong resistance to starvation. Adults, on the other hand had a much shorter life span when starved.

### FOOD CONSUMPTION

Using leaves infested with both Florida red scale and purple scale, the number of scales consumed by adult beetles and fourth instar larvae was determined in the laboratory. Table III presents data for adult beetles. There was a pronounced tendency for the adults to feed by prying the scale armors loose with the labrum rather than by chewing holes. The hourly consumption of scales was similar to that of other lady beetles (Clausen, 1916). Larvae fed by chewing holes in the scale armors and ate an average of only 1.06 scales per hour with a maximum of 1.88.

### FOOD PREFERENCE

Food preference studies were conducted under both laboratory and grove conditions.

In the laboratory adult beetles were given the choice of resting or feeding on Florida red scale or purple scale infested leaves or on clean leaves for several test periods. Results of a series of these tests are given in Table IV. On average, about 40% of the beetles were observed feeding at a given time. A slight perference for Florida red scale was exhibited by feeding beetles.

Similar figures were obtained from counts of beetles in citrus groves moderately infested with Florida red scale and purple scale. Of 283 beetles observed 31.4% were feeding on Florida red scale and 22.0% on purple scale, while 46.3% were not feeding. When Florida red scale infestations

TABLE I

SUMMARY OF LARVAL AND PUPAL DEVELOPMENT OF *Chilocorus stigma* (Say) AT THREE DIFFERENT TEMPERATURES

| Stage | 80 F. (71 larvae) | | | | 70 F. (76 larvae) | | | | 62 F. (76 larvae) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Mort. | Days | | | % Mort. | Days | | | % Mort. | Days | | |
| | | Max. | Min. | Mean | | Max. | Min. | Mean | | Max. | Min. | Mean |
| First Instar | 23.9 | 9 | 3 | 5 | 14.5 | 10 | 4 | 6 | 39.4 | 24 | 7 | 10 |
| Second Instar | 13.2 | 10 | 2 | 4 | 3.1 | 14 | 2 | 5 | 19.5 | 20 | 6 | 10 |
| Third Instar | 2.1 | 7 | 2 | 5 | 7.6 | 13 | 4 | 7 | 37.8 | 22 | 7 | 12 |
| Fourth Instar | 21.4 | 10 | 7 | 8 | 18.3 | 15 | 10 | 13 | 78.3 | 29 | 25 | 28 |
| Pupa | 7.4 | 10 | 6 | 8 | 2.1 | 13 | 10 | 11 | 20.0 | 24 | 20 | 22 |
| Complete Cycle | 29.6 | 46 | 20 | 30 | 38.2 | 65 | 30 | 42 | 94.7 | 119 | 65 | 82 |

TABLE II

LONGEVITY OF CRITICAL STAGES OF *Chilocorus stigma* (SAY) IN THE LABORATORY AT 80° F

| Stage | Food Provision | Number Individuals | Longevity in Days | | |
|---|---|---|---|---|---|
| | | | Max. | Min. | Mean |
| First Instar | Fed | 71 | 9 | 3 | 5* |
| First Instar | Starved | 125 | 4 | 2 | 3 |
| Fourth Instar | Fed | 42 | 10 | 7 | 8* |
| Fourth Instar | Starved | 27 | 14 | 3 | 7.9 |
| Adults | Fed | 72 | 133 | 6 | 32 |
| Adults | Starved | 40 | 14 | 2 | 6.5 |

*Figures for fed larvae represent time spent in respective stadia.

TABLE III

MEAN NUMBER AND PERCENTAGE OF SCALES EATEN PER HOUR BY *Chilocorus stigma* (SAY) ADULTS UNDER LABORATORY CONDITIONS BY EATING THROUGH THE ARMOR OR PUSHING IT ASIDE

| Test Date | No. Test Hours* | Mean No. Scales/Hr. | Percentage Armor Removed | Percentage Armor Eaten |
|---|---|---|---|---|
| 7/30/53 | 1 | 4.0 | 75.0 | 25.0 |
| 7/30/53 | 1 | 4.0 | 91.6 | 8.3 |
| 7/30/53 | 1 | 2.6 | 100.0 | 0.0 |
| 7/30/53 | 1 | 1.3 | 75.0 | 25.0 |
| 7/30/53 | 1 | 2.0 | 66.6 | 33.3 |
| 7/29/53 | 2 | 3.3 | 95.5 | 5.5 |
| 7/29/53 | 2 | 3.5 | 95.2 | 4.7 |
| 8/4/53 | 4 | 1.2 | 78.6 | 21.4 |
| 7/31/53 | 16 | 1.8 | 83.0 | 16.9 |
| 8/ 2/53 | 18 | 4.0 | 80.5 | 19.5 |
| Average | 4.7 | 2.7 | 84.1 | 15.9 |

*Three laboratory reared beetles were utilized in each test.

where light, however, the beetles fed entirely on purple scale.

The effect of food preference on population size was also investigated. Variable results were obtained. Mean percentage infestations of Florida red scale and mean number of lady beetle adults and larvae per tree were compared in 76 groves in June, July and August of 1951 and 1952. When the Florida red scale infestations varied from 7.0% to 12.5% to 30.5% to 53.0% the lady beetle populations were 8, 14, 8 and 15 respectively, indicating no correlation between the amount of preferred food and beetle populations.

TABLE IV

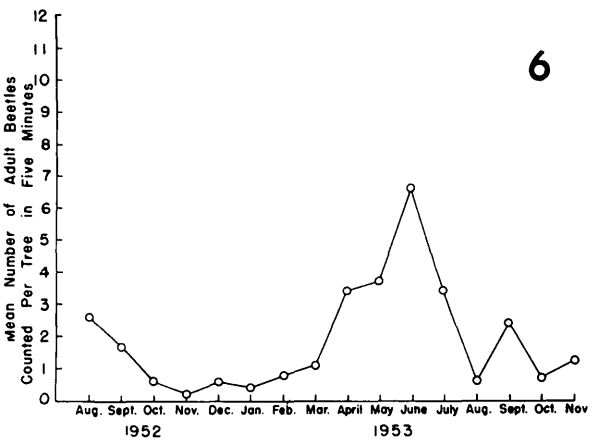
PERCENTAGE OF *Chilocorus stigma* (SAY) ADULTS FEEDING ON FLORIDA RED SCALE, PURPLE SCALE, OR NOT FEEDING UNDER LABORATORY CONDITIONS

| TEST DATE | NUMBER BEETLES | NUMBER READINGS | PERCENTAGE AT FLA. RED SCALE | PERCENTAGE AT PURPLE SCALE | PERCENTAGE NOT FEEDING |
|---|---|---|---|---|---|
| 3/ 4/53 | 9 | 4 | 3.4 | 14.5 | 81.2 |
| 3/ 5/53 | 20 | 10 | 4.1 | 9.4 | 86.5 |
| 3/ 6/53 | 18 | 6 | 23.4 | 20.0 | 56.5 |
| 3/ 6/53 | 26 | 5 | 17.9 | 26.5 | 55.5 |
| 3/ 7/53 | 23 | 5 | 35.2 | 11.7 | 53.1 |
| 3/ 9/53 | 22 | 15 | 46.2 | 18.2 | 35.6 |
| 3/10/53 | 17 | 15 | 21.3 | 30.9 | 47.8 |
| 3/11/53 | 20 | 13 | 37.3 | 16.2 | 46.5 |
| 4/23/53 | 20 | 8 | 20.0 | 14.4 | 65.6 |
| 4/24/53 | 20 | 9 | 15.7 | 28.3 | 56.0 |
| 4/25/53 | 20 | 5 | 9.0 | 13.0 | 78.0 |
| 4/27/53 | 20 | 15 | 23.3 | 25.0 | 51.7 |
| Avg. | 19.6 | 9.2 | 21.4 | 19.0 | 59.5 |

## FECUNDITY

The reproductive rate of the species was determined in the laboratory. Virgin males and females were confined on Florida red scale and as mating was observed mated pairs were isolated and the egg production recorded. Egg laying began 10 to 13 days after emergence from the pupa. The average production of five females was 168 eggs with a maximum of 299 and a minimum of 42.

Several laboratory tests were conducted to determine whether the fecundity of this lady beetle varied with the type of food consumed. Beetles obtained from pupae collected in a Polk County grove were fed Florida red scale, purple scale or both alternately. Ten females fed Florida red scale laid 324 eggs on 38 days, while ten fed Florida red scale and purple scale on alternate days laid 80 on 21 days and ten fed purple scale laid 3 on 2 days. The effect of food on fecundity was also indicated in a 12-day delay in first deposition for beetles fed alternately on Florida red scale and purple scale and a 24-day delay for those fed purple scale. Vitality of the beetles was also affected by the food. Only one of the beetles fed Florida red scale died during the 42-day test period, while all died on the purple scale diet. Viability of eggs laid during the experiment was very high; less than one percent failed to hatch.




The possibility of physiological races differing in fecundity was also investigated. Specimens were collected from large populations in a Pinellas County grove where yellow scale, *Aonidiella citrina* (Coq.), was present but Florida red scale absent and in a Merritt Island grove with a very low Florida red scale population. The fecundity of these beetles when fed Florida red scale or purple scale in the laboratory is compared with that of the Polk County beetles in Table V. In every case more eggs were produced on Florida red scale than on purple scale.

TABLE V

FECUNDITY OF TEN *Chilocorus stigma* (Say) FEMALES FROM GROVES AT THREE LOCATIONS, POLK COUNTY, PINELLAS COUNTY AND MERRITT ISLAND, FED PURPLE OR FLORIDA RED SCALE. 1953.

| LOCALITY | NO. TEST DAYS | NO. EGGS LAID ON | | PERCENTAGE GROVE INFESTATION* | | |
|---|---|---|---|---|---|---|
| | | Purple Scale | Florida Red Scale | Purple Scale | Florida Red Scale | Yellow Scale |
| Polk County..... | 42† | 3 | 324 | 30 | 28 | 0 |
| Pinellas County.. | 26 | 14 | 74 | 55 | 0 | 15 |
| Merritt Island.... | 20 | 1 | 75 | 28 | 1.2 | 0 |

*Percentage infestation based on number of leaves with at least one living female scale in a 50-leaf, randomly picked sample.

†Each experiment was terminated when all beetles fed purple scale had died.

## CONCLUSIONS AND DISCUSSION

The twice-stabbed lady beetle, *Chilocorus stigma* (Say) is the most common lady beetle attacking scale insects on citrus in Florida.

The eggs are laid in protected places near the

larval food. Pupation takes place on tree limbs and twigs. Adults and larvae feed on half to full grown scales but do not eat eggs and crawlers in significant quantities. The species completes a life cycle involving seven stages of development in about one mouth at summer temperatures and about three months at winter temperatures. Although the species appears to have no common insect parasites, two fungi are known to attack the adults and larvae.

Populations of the species are lowest in the fall and winter when low temperatures result in an extended life cycle. Mortalities caused by parasitic fungi during the rainy season probably are also a factor in reducing populations. Beetles are most numerous in the late spring and early summer as a result of the increased food supply at that time and the shorter life cycle at higher temperatures.

The twice-stabbed lady beetle prefers Florida red scale to the more common purple scale but there is no consistent correlation between the abundance of preferred food and numbers of beetles. As the species is a voracious feeder, relatively resistant to starvation, and possesses a high fecundity on Florida red scale, this lack of a host-predator correlation is perplexing. Apparently some, as yet, unknown factor is limiting the effectiveness of the species.

When other predators and parasites of Florida red scale occur simultaneously with the twice-stabbed lady beetle, the species may function as a factor in biological control. Alone, however, the beetle seems incapable of reducing scale populations and does not appear to be as important as formerly believed.

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DISTRIBUTIONAL STUDIES OF PARASITIC ARTHROPODS IN UTAH, DETERMINED AS ACTUAL AND POTENTIAL VECTORS OF ROCKY MOUNTAIN SPOTTED FEVER AND PLAGUE, WITH NOTES ON VECTOR-HOST RELATIONSHIPS, by D. ELDEN BECK. Brigham Young University Science Bulletin, Biological Series, vol. 1, no. 1. Pp. ii + 64, 23 figs. 1955.

This new series of biological publications has made an auspicious beginning. Dr. Beck, with the collaboration of his associates and graduate students, has produced an important monograph of the subject indicated quite fully by the title. After an extended introduction, in which the ecological background is given, particularly, in relation to the desert, foothill, and mountain communities (with superb photographic illustrations), the work is divided into two parts, the first dealing with plague and the second with Rocky Mountain spotted fever. The accumulated information and tabulated material, with its reference to an intensive area-study, will be of considerable interest to anyone studying these diseases and their vectors, reservoirs, and hosts. Of incidental historical interest is the evidence that seems to indicate that several early Mormon settlers died of Rocky Mountain spotted fever and that Brigham Young himself had the disease, but recovered.

MAURICE T. JAMES.