To the Graduate Council:

I am submitting herewith a thesis written by Joe Davenport Simpson entitled "The Biology of Five Scale Insects (Homoptera: Coccoidea) in Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Biology.

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Vice Chancellor
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THE BIOLOGY OF FIVE SCALE INSECTS (HOMOPTERA: COCCOIDEA) IN TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Joe Davenport Simpson

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ABSTRACT

The biologies of two soft scales, Coccus hesperidum Linnaeus and Toumeyella liriodendri (Gmelin) (Homoptera: Coccidae),and three armoured scales, Chionaspis kosztarabi Takagi and Kawai, Pinnaspis aspidistrae (Signoret), and Quadraspidiotus juglansregiae (Comstock) (Homoptera: Diaspididae), were investigated at the University of Tennessee, Agriculture Campus using populations in Tennessee. All studies were conducted from 1975 to 1976 except those for T. liriodendri were from 1973 to 1976.

The brown soft scale, C. hesperidum, was a multivoltine parthenogenetic species on spider plant, Chlorophytum comosum Wood. There were seven to eight generations per year. One mite species was collected in close association with the brown soft scale with no parasites or predators found.

Biological studies revealed the tuliptree scale, T. liriodendri, to be univoltine and ovoviparous on yellow-popular, Liriodendron tulipifera L. overwintering as first and second instars. Four Formicids, one Dipteran and one Hymenopterous wasp were found collecting honeydew produced by the tuliptree scale. The tuliptree scale was parasitized by three Hymenopterous species and one Dipteran and preyed upon by one Lepidopteran and four Coccinellid species. Two other Hymenopterous parasites and one mite were collected in close association with this species.

Chionaspis kosztarabi was bivoltine and oviparous on white ash, Fraxinus americana L., overwintering as fertilized adult females. One Hymenopterous parasite was found parasitizing C. kosztarabi second instar females and one scavenger mite was found in close association with adult females.

Studies revealed the fern scale, P. aspidistrae, to be a multivoltine parthenogenetic species on lilly turf, Liriope spicata, overwintering as adult females. One Hymenopterous parasite was found parasitizing second instar females.

The walnut scale, Q. juglansregiae, was bivoltine and oviparous on flowering dogwood, Cornus florida L., overwintering as second instar males and females. One Hymenopterous parasite was found parasitizing second instar females. Three mite species were found in close association with this species.

Seasonal history tables of the four latter species are included along with photographs of each biological study and mounting methods. All nymphal instars and adults are discussed.

Selected chemical insecticides were evaluated in greenhouse studies in 1975 to compare their efficiency in controlling brown soft scale on C. comosum and fern scale on L. spicata. Insecticides tested were orthene 75W, two rates of carbaryl 50W, and dimethoate 2E. All chemical treatments gave effective control of both species.

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CHAPTER I

INTRODUCTION AND REVIEW OF THE LITERATURE

Scale insects are among the most destructive pests of ornamental trees and shrubs. Their minute size, reproductive potential, and the difficulty of controlling them, combine to make them the most formidable of pests (Comstock, 1916). The damage by scales is frequently underestimated or even entirely overlooked until plants are severely injured (Drake and Guthrie, 1931). Scales damage plants by piercing the tissue with their mouthparts and sucking large quantities of sap causing a loss of plant vigor. In addition some species excrete large quantities of honeydew which serves as a medium for the growth of saprophytic fungi. Fungi inhibit photosynthesis and ruin the aesthetic quality of plants. The injury a particular species inflicts on a plant depends largely upon feeding activities, rate of reproduction and the abundance of natural enemies and climatic factors (Drake and Guthrie, 1931).

Soft scales belong to the family Coccidae. These insects have exposed bodies which may be soft or hard (Dekle, 1968). Many species are heavily sclerotized and often very convex (Williams and Kosztarab, 1972).

The brown soft scale, Coccus hesperidum Linnaeus, is a soft scale species with a worldwide distribution, existing in greenhouses in temperate regions and outdoors in tropical or subtropical regions on a wide variety of host plants (Williams and Kosztarab, 1972). In addition to ornamentals it is a very significant pest in citrus groves

(Williams and Kosztarab, 1972). Linnaeus described C. hesperidum. Subsequent workers were primarily concerned with its taxonomic status. Fonseca (1954, 1955, 1956) and Saakyan-Baranova (1964) did the most extensive biological studies.

The tuliptree scale, Toumeyella liriodendri (Gmelin), is a soft scale native to the yellow-poplar range of eastern North America (Burns and Donley, 1970) and is an occasional pest of ornamental plantings of yellow-poplar and magnolia in California (Armitage, 1947). This species limits natural regeneration of yellow-poplar, particularly in abandoned fields and pastures (Burns and Donley, 1970). Gmelin (1789) described the tuliptree scale while Burns and Donley (1970) provided the most extensive biological study of the species.

Armoured scales belong to the family Diaspididae. These insects secrete a waxy, hardened covering called a test which is not an integral part of the insect's body. The test is composed of secreted wax incorporated with discarded exuviae. The female is always wingless while males may be winged or non-winged (Dekle, 1968).

Chionaspis kosztarabi Takagi and Kawai is an armoured scale native to eastern North America where it primarily infests ash, Fraxinus sp. (Willoughby and Kosztarab, 1974). This species has not been recognized as a significant pest primarily because it was not recognized as a distinct species differing from C. gletsiae Sanders until 1967 (Willoughby and Kosztarab, 1974). It may be economically damaging to nursery stock and ornamental plantings. Takagi and Kawai described C. kosztarabi while Willoughby and Kosztarab (1974) did the most comprehensive morphological and biological study.

The fern scale, Pinnaspis aspidistrae (Signoret) is a cosmopolitan armoured scale. It exists on a diverse host group in greenhouses in temperate regions and outdoors in tropical and subtropical regions. This species is an economic pest in greenhouses and on ornamentals (Werner 1931). Signoret (1869) described P. aspidistrae. Werner (1931) provided the most extensive biological study while Ferris (1947) did the most extensive taxonomic study of the species.

The walnut scale, Quadraspidiotus juglansregiae (Comstock), is an armoured scale found in Holoartic Regions on various hosts plants (Ferris, 1938; Dekle, 1965). This species causes tree mortality especially in cities or at least gives trees an unhealthy appearance (Houser, 1918). The walnut scale was described by Comstock (1881). Later investigations were primarily taxonomic and added little to Comstock's original description.

Nothing has been published about scale insects in Tennessee. Therefore, research was initiated in 1975 to investigate the biology of these five species. The objective was to determine the biology and development of each species. Chemical control studies were conducted on Coccus hesperidum and Pinnaspis aspidistrae which represented members from both families. All nymphal instars and adults were studied.

CHAPTER II

MATERIALS AND METHODS

Material

Material was collected at the University of Tennessee, Agriculture Campus. Biological studies were conducted both in the laboratory and greenhouse. Specimens were mounted on slides for morphological observation (see Methods).

Collecting

Live specimens were collected and notes were taken on their biology. Scale insects were collected *in situ* by cutting twigs, bark, and leaves at random from the host plant with garden clippers. Living insect material was used in the laboratory for rearing, egg counts, and mounting. In some instances small populations warranted the individual removal of scale insect speciments from the host plant in order to maintain a viable population to collect from. Specimens were preserved in 70% ethyl alcohol until mounted. Ants, parasites, and predators found in direct association with the scale species were collected. These specimens were either pinned or preserved in a permanent preservative. Mites found under scale covers were either placed in vials containing permanent preservative or mounted directly in Hoyer's medium on slides.

Collected material was placed in cellophane bags and labeled (Plate I-A). The bags were left open two or three days allowing plant

Plate I. Materials and methods: biological aspects of *Coccus hesperidum* L.

Photo A. Cellophane bags used for storage of specimens on plant material and rearing.

Photo B. Cardboard cage with transparent vial on an infested limb for rearing *Toumeyella liriodendri* (Gmelin).

Photo C. Randomized complete block design.

Photo D. *Coccus hesperidum* L. on *Chlorophytum comosum* Wood.

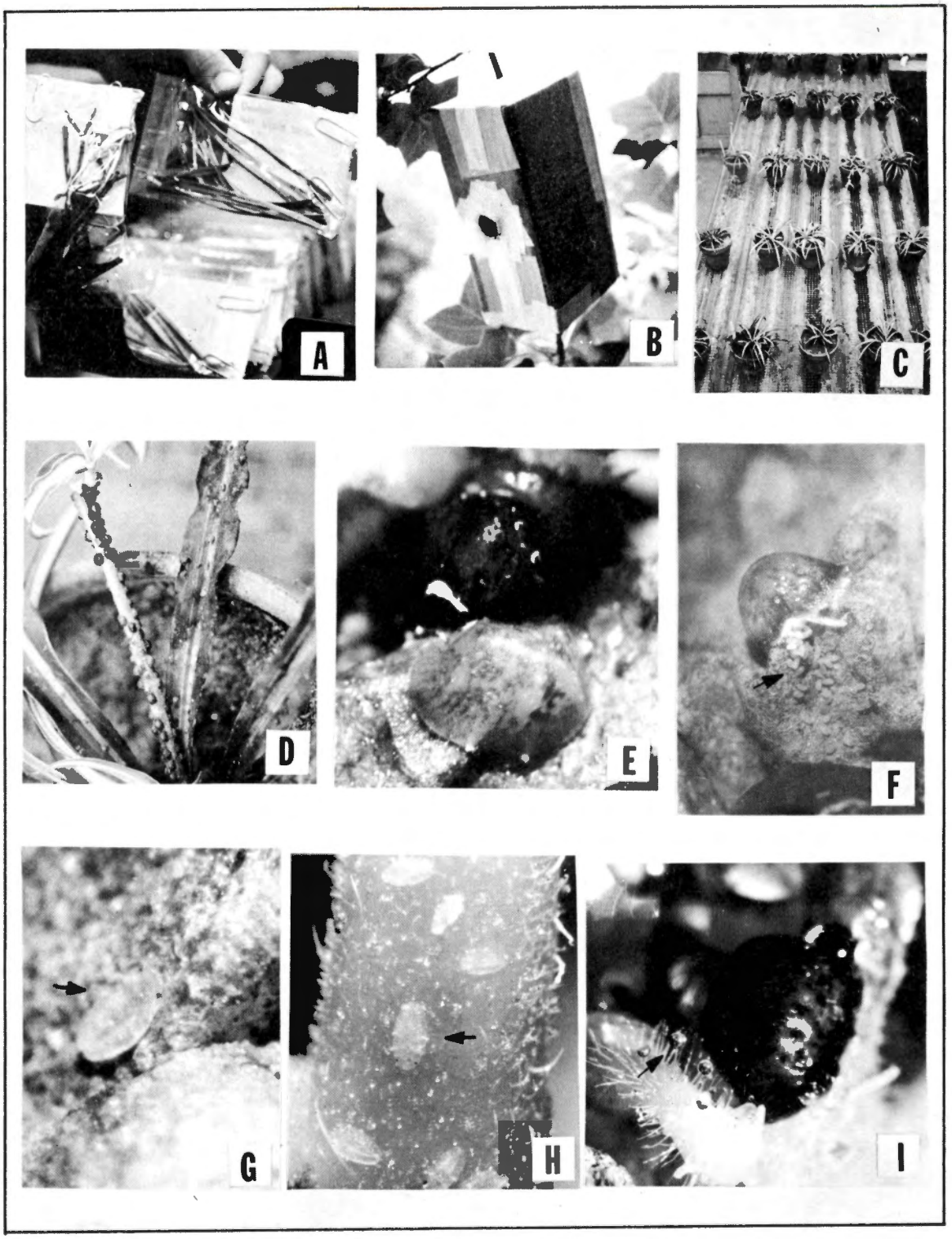
Photo E. *Coccus hesperidum* L. mottled with dark pigmentation indicating egg development.

Photo F. *Coccus hesperidum* L. eggs.

Photo G. Mobile stage of *Coccus hesperidum* L. first instar.

Photo H. Sessile stage of *Coccus hesperidum* L. first instar.

Photo I. Honeydew produced by *Coccus hesperidum* L.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material time to dry and preventing mold from ruining the specimens. Bags were then closed and sealed with paper clips and used as rearing chambers for males and parasites. They were checked every two or three days for emergence.

Rearing

Coccus hesperidum was reared in the laboratory on sprouting potatoes which served as a substitute host plant. A population was also maintained on Chlorophytum comosum in the greenhouse. Toumeyella liriodendri males were reared on the tree by attaching a cardboard cage with a transparent vial in the side to an infested limb (Plate I-B). The males emerged and flew toward the light into the vial. Diaspidid males and their parasites were reared from material placed in cellophane bags in the laboratory.

Fecundity

Fecundity was determined by egg counts. Females which had completed oviposition were selected at random. The test was removed and the eggs allowed to spill into a petri dish divided into numbered sections. The eggs in each section were counted under a binocular dissecting microscope and totaled.

Color Coding

The following procedure was adapted from Kosztarab (1963). Live material was placed on a glass slide and compared with hues in the 1952 pocket edition of Munsell's Book of Color under a binocular dissecting microscope. When the appropriate color pattern was obtained

the technical description of the color was recorded (e.g., yellowish-red on chart 5.0, color value No. 7, chroma value No. 8, would be designated 5.0 yr/7/8).

Mounting Methods

Specimens were mounted with the aid of a Nikon SMZ-2 binocular dissecting microscope. Live material was placed in 70% alcohol for several hours before mounting to fix the tissues. Specimens in alcohol were mounted according to the following procedure which is a modification of Wilkey's (1962) Method and is outlined by Lambdin and Kosztarab (1973):

1. Specimens were placed in a porcelain dish containing 10% KOH and heated rapidly until the KOH began to bubble.

2. A small incision was made and all the body contents pressed out with a small spatula while still in the KOH.

3. Specimens were transferred to a small watchglass containing Essigs Aphid Fluid for additional clearing. Gentle heating over a hotplate for 10 to 15 minutes aided in clearing.

4. One or two drops of staining solution were added to the Essigs Aphid Fluid and gently heated for 15 to 60 minutes to speed staining.

5. Specimens were transferred to 70% ethyl alcohol for five to 15 minutes to remove any excess stain.

6. Specimens were transferred to clove oil for five to 15 minutes.

7. Specimens were mounted in Canada balsam under a circular cover glass.

8. Slides were permanently marked with a diamond-point pencil.

9. Slides were placed in a drying oven at 38°C for approximately two weeks before labeling.

The length of time specimens were left in Essigs Aphid Fluid or in the staining solution was not critical because they would rarely disintegrate or overstain.

First instars and males required more delicate treatment by omitting steps 2 and 6. Better slide mounts were prepared by placing them directly in Essigs Aphid Fluid and gently heating them until clear.

Poorly mounted specimens were cleared and remounted. They were first immersed in xylene until the cover glass could be easily removed then remounted by reversing the procedure above.

CHAPTER III

BIOLOGY OF *COCCUS HESPERIDUM* L. WITH NOTES ON ITS CONTROL

The brown soft scale, *Coccus hesperidum* L., is a greenhouse pest in Tennessee and is not found outdoors. High fecundity enables this species to rapidly buildup large populations. Plant damage by this pest occurs in two principle ways: sucking sap causing a loss of plant vigor, and excreting an abundance of honeydew providing a substrate for development of saprophytic fungi.

Chemical control has been limited to populations in citrus groves. A better biological understanding of *C. hesperidum* in the greenhouse is necessary in developing proper timing schedules for control.

Coccus hesperidum was first described by Linnaeus (1758). Sulzer (1761) established the type species of *Coccus* as *C. hesperidum* and Fernald (1902, 1903, 1906) retained *C. hesperidum* as the type species.

Morphological variants of *C. hesperidum* in different localities on various host plants has led to confusion surrounding its taxonomy. Most early authors referred to this insect as *Lecanium hesperidum*. Fernald (1903) listed *C. hesperidum* L. in her catalogue and presented an extensive list for the species. A few workers continued to refer to the brown soft scale as *L. Hesperidum*, i. e., Comstock (1881), Thro (1903), or Macgillivray (1921), but most have agreed with the classification of Fernald, i.e., Essig (1915); Fonseca (1953); Borchenius (1957); or Saakyan-Baranova (1964).

Thomsen (1927, 1929) introduced the idea of C. hesperidum having two races. Fonseca (1953, 1954, 1955, 1956) did the most comprehensive study of C. hesperidum which included: a historical review of publications; taxonomy; morphology; biology; and geographical distribution in relation to climate. Saakyan-Baranova (1964) did an extensive biological study showing the average life span of C. hesperidum to be 100 days at 19.5°. He studied and described the rarely found males as did Gilomee (1967). The biology of the immatures was published by Annecke (1966).

Lewallen (1954) and Reed, et al. (1968) improved laboratory techniques for reproducible controlled rearing of the brown soft scale. Hoelcher (1967) studied wind dispersal of brown soft scale crawlers and found them capable of being transported 179 feet from a test site. Hart and Meyers (1968) used infrared aerial color photography to detect populations of brown soft scale in citrus groves. This is an early warning system used for the detection of progressive buildups of C. hesperidum.

Morphological characteristics separating instars of the brown soft scale female have been discussed by Williams and Kosztarab (1972).

Chemical control of the brown soft scale has been attempted on many occasions in both field and greenhouse experiments. An increase in populations of brown soft scale have been associated with the application of parathion to citrus trees (Bartlett, et al., 1951; Elmer, et al., 1951; Annecke, 1959; Hart, et al., 1966; Hart and Ingle, 1971). Some increase in population numbers occurred with

applications of aldrin and dieldrin (Elmer, et al., 1951). Hart, et al. (1966) found aerial applications of malathion, azinphos-methyl, and carbaryl suppressive to brown soft scale populations on citrus. Malathion, malathion-parathion sprays and soil applied granular Temik also provided good control on citrus (Elmer and Ewart, 1954; Johnson and Thompson, 1954; Hart and Ingle, 1967; Boling and Dean, 1968).

Specimens were reared in the laboratory on potatoes. The spider plant, Chlorophytum comosum Wood, was used as a host for C. hesperidum during chemical control studies. First instars were brushed from potato tubers with a camel hair brush onto the leaves and allowed to mature and reproduce.

Before insecticidal application the stage of development was determined. Plants were arranged in a randomized complete block replicated eight times (Plate I-C, page 5). Insecticides were applied as foliar sprays on August 2, 1975 and evaluated on August 7, 1975. Two leaves per plant infested with 10 scale insects were tagged with a white thread for ease in observation.

Biology

Biological studies of C. hesperidum revealed it to be multivoltine, parthenogenetic, and oviparous on C. comosum in the greenhouse and on potato sprouts in the laboratory. There were seven to eight overlapping generations per year and the length of each generation varied. Saakyan-Baranova (1964) reported generation lengths ranging

from 36 to 90 days. He believed this variability to be a result of intensive activity of the soft scale coinciding with active growth periods of the food plants, particularly when new shoots appear or during the flowering or fruitbearing periods, and seasonal fluctuations, in temperature affecting population numbers and the duration of its life cycle. Development is retarded with temperatures above 25°C (Saakyan-Baranova, 1964). Since temperature and photoperiod are directly related, it is the photoperiod which probably affects the period of development rather than temperature, since host plants are affected by photoperiod rather than temperature.

Brown soft scale females were found on leaves and shoots of C. Comosum (Plate I-D, page 5). Body size and shape varied with the host plant and position on the plant becoming increasingly convex with age. Young adults were ovate and were pale yellow, 5.0 y/8/4, in color, becoming mottled with dark pigmentation, 5.0 yr/4/6, when eggs began developing (Plate I-F, page 5). Mature females developed a concave ventral surface forming an egg chamber. They became brown, 5.0 yr/4/4, as eggs were laid. The average number of eggs laid over a three to four day period was 1224(624-1773). Eggs were laid beneath the venter filling the egg chamber where they matured and hatched within 10 to 14 days.

Eggs (Plate I-F, page 5) were oval, 0.3 mm long and 0.2 mm wide. They were initially white turning pink, 5.0 r/8/4, within ca. three days. Eggs were found to be in different states of development beneath the female, therefore, hatching and first instar emergence covered a

period of three to four days. A cottony filamentous mass surrounded the eggs, and many first instar crawlers became tangled in this mass and died. The ovisacs remained in a shriveled mass under the female body.

First instars had two distinct periods of development: the mobile state (Plate I-G, page 5) and the sessile state (Plate I-H, page 5) during which they were attached to the host plant. Crawlers upon emergence were oval, 0.45 mm long, 0.24 mm wide, and were yellowish-red, 5.0 yr/7/4, in color. Crawlers remained active from a few hours to three or four days traveling approximately one meter from eclosion to the time of attachment to the plant (Saakyan-Baranova, 1964). Crawlers placed on a white index card moved approximately 1-25 mm per minute and exhibited positive phototropism. Once a suitable feeding site had been found, the crawler ceased moving, drew its legs to the ventrum, inserted its stylets into the plant tissue and began feeding.

First instars which had settled and were attached to the host plant differed in appearance from active crawlers. There was a color change from the characteristic yellowish-red, 5.0 yr/7/4, body color of the early crawler to a light yellow, 5.0 y/8/4, body color of the sessile first instar, and a size increase with the body becoming flattened dorso-ventrally once feeding was initiated.

First instars differed from second instars very little externally. First instars could be recognized by the presence of long anal setae which were lost with the exuviae at the first molt 10 to 15 days after initial attachment. Second instars were larger in size. Both first

and second instars had light yellow, 5.0 y/8/4, body color and could disengage their mouthparts from the host plant when conditions were unfavorable and move to another location. After ca. 14 days the second instar molted to the third instar female.

Males were not observed but have been encountered on various occasions by other investigators. A description of the rare males was presented by Giliomee (1967). Saakyan-Baranova (1964) reported that males differed in appearance from the females from the second instar onwards and in contrast to the females lived only two or three days.

Thomsen (1927) concluded from cytological studies that two races of the brown soft scale exist: one purely parthenogenetic, consisting exclusively of females, and the other bisexually parthenogenetic, consisting of males and females. The former reproduces by obligatory thelytoky, i.e., no fertilization occurs, resulting in only females. The latter reproduces by faculative thelytoky, i.e., an unfertilized egg develops into a female and both sexes develop from fertilized eggs. In Tennessee only the purely parthenogenetic race consisting exclusively of females has been found.

Honeydew was secreted in large amounts by the brown soft scale throughout its development (Plate I-I, page 5). The honeydew covered the surface of leaves and branches and served as a medium for the growth of sooty mold fungi. The fungi inhibited photosynthesis by the plants causing stunting and premature leaf drop, and it greatly reduced the aesthetic quality of plants because of its sooty appearance. Saakyan-Baravova (1964) reported honeydew secretion was particularly intensive

when unfavorable conditions existed, for instance when scales were placed in direct sunlight or water.

One mite species, Tyrophagus sp. (Acarina: Acaridae) was found in close association with C. hesperidum. Baker and Wharton (1964) recorded the Acaridae as being neither parasites nor predators.

Control

Selected chemical insecticides were evaluated in greenhouse studies at the University of Tennessee in 1975 to compare their efficiency in controlling brown soft scale on spider plant. Insecticides tested were orthene (O,S-dimethyl N-acetyl phosphoramidothioate) 75W, carbaryl (1-Naphthyl methylcarbamate) 50W, and dimethoate (O,O-Dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate) 2E. All chemicals except orthene 75W were applied to stems and leaves to the point of runoff as 0.5% active ingredient sprays. Orthene 75W was applied as both a 0.5% and a 1.0% active ingredient spray. All stages of development were present when sprayed with first and second instars most abundant.

Results and discussion. There was no significant difference between chemical treatments at the 5% level using Duncan's New Multiple Range Test (Table 1). There was a significant difference between all chemical treatments and the untreated check at the 1% level using Duncan's New Multiple Range Test. All chemical treatments gave effective control of all three instars of development. The mortality of Coccus hesperidum on the untreated plants was higher than expected.

TABLE 1

COMPARISON OF FOUR INSECTICIDAL SPRAYS
ON COCCUS HESPERIDUM, L. 1975

Treatment	AI %	Instar Mortality			Mean[1]
		First	Second	Third	
Control	--	28	32	17	4.13 a[2]
Orthene 75W	0.5	30	39	9	9.62 b
Orthene 75W	1.0	36	36	8	9.75 b
Dimethoate 2E	0.5	36	32	10	9.25 b
Carbaryl 50W	0.5	18	13	2	9.75 b

[1]Mean number dead for eight replicates.

[2]Means followed by the same letter are not significantly different at the 5% level by Duncan's New Multiple Range Test.

A survey of the test plants three months after spraying showed them to be free of scales. Dimethoate 2E was very phytotoxic, killing 50% of the plants sprayed. These plants wilted and turned brown two to eight weeks after spraying.

CHAPTER IV

BIOLOGY OF TOUMEYELLA LIRIODENDRI (GMELIN)

The tuliptree scale, Toumeyella liriodendri (Gmelin), is a pest of yellow-poplar, Liriodendron tulipifera L., in Tennessee. This scale insect damages its host by sucking sap causing a loss of plant vigor, killing limbs, terminals, or the tree itself, excreting an abundance of honey-dew providing a substrate for development of saprophytic fungi, and ruining the aesthetic appearance of ornamental plants.

Gmelin (1789) described the tuliptree scale as Coccus liriodendri. Cook (1878) referred to the species as Lecanium tulipiferae. King (1902) transferred the insect to Eulecanium. Fernald (1903) referred to the species as Eulecanium liriodendri (Gmelin). Sanders (1909) studied the taxonomic status of the species and placed it in the genus Toumeyella.

Houser (1918) and Burns and Donley (1970) provided the most extensive biological studies. Morphological characteristics were discussed by Dietz and Morrison (1916) and Williams and Kostarab (1972).

The tuliptree scale was studied in the field and laboratory from 1973 to 1976 in Knox County, Tennessee. Biological observations were made from weekly collections.

Fecundity was determined by placing gravid females in vials and counting the number of crawlers that emerged.

Adult parasites were collected with aspirators and sweep nets or

reared from scales in the laboratory. Predators were collected when found in close association with this species.

Biology

Biological studies revealed T. liriodendri to be univoltine and ovoviparous on L. tulipifera overwintering as first and second instars. It has been found to be multivoltine in the extreme southern parts of its range (Beal, 1952).

Adult females were found in large clusters on twigs and branches (Plate II-A) from early April until mid-March of the following year (Figure 1) and grew rapidly from May until mid-August. Females were oval, very convex, 5.0 mm long, 4.7 mm wide, and 4.0 mm tall. One extremely large individual, 8.0 mm long, 6.5 mm wide, and 5 mm tall was found. Females were dark reddish-purple, 5.0 r/3/2, in color at maturity. Embryonic development within adult females occurred from late August to mid-December. Two gravid individuals were collected on February 18, 1975, but no crawlers were present. The average number of crawlers produced by a female over a two month period was 2594(1567-3426).

Males could not be identified until late April when their tests began to elongate and become lighter in color. Males were found either in close association with females (Plate II-B) or in separate clusters. Prepupae were present from late April to mid-May. Pupae were observed from early May until late May. Pupal tests were shiny, white, and opaque, covering the tan pupae (Plate II-C). Adult males (Plate II-D) emerged from mid-May to late May and mated with the adult females.

Plate II. Biological aspects of Toumeyella liriodendri (Gmelin).

Photo A. Toumeyella liriodendri (Gmelin) adult females on Liriodendron tulipifera L.

Photo B. Toumeyella liriodendri (Gmelin) males in close association with females.

Photo C. Toumeyella liriodendri (Gmelin) pupal tests.

Photo D. Toumeyella liriodendri (Gmelin) adult male.

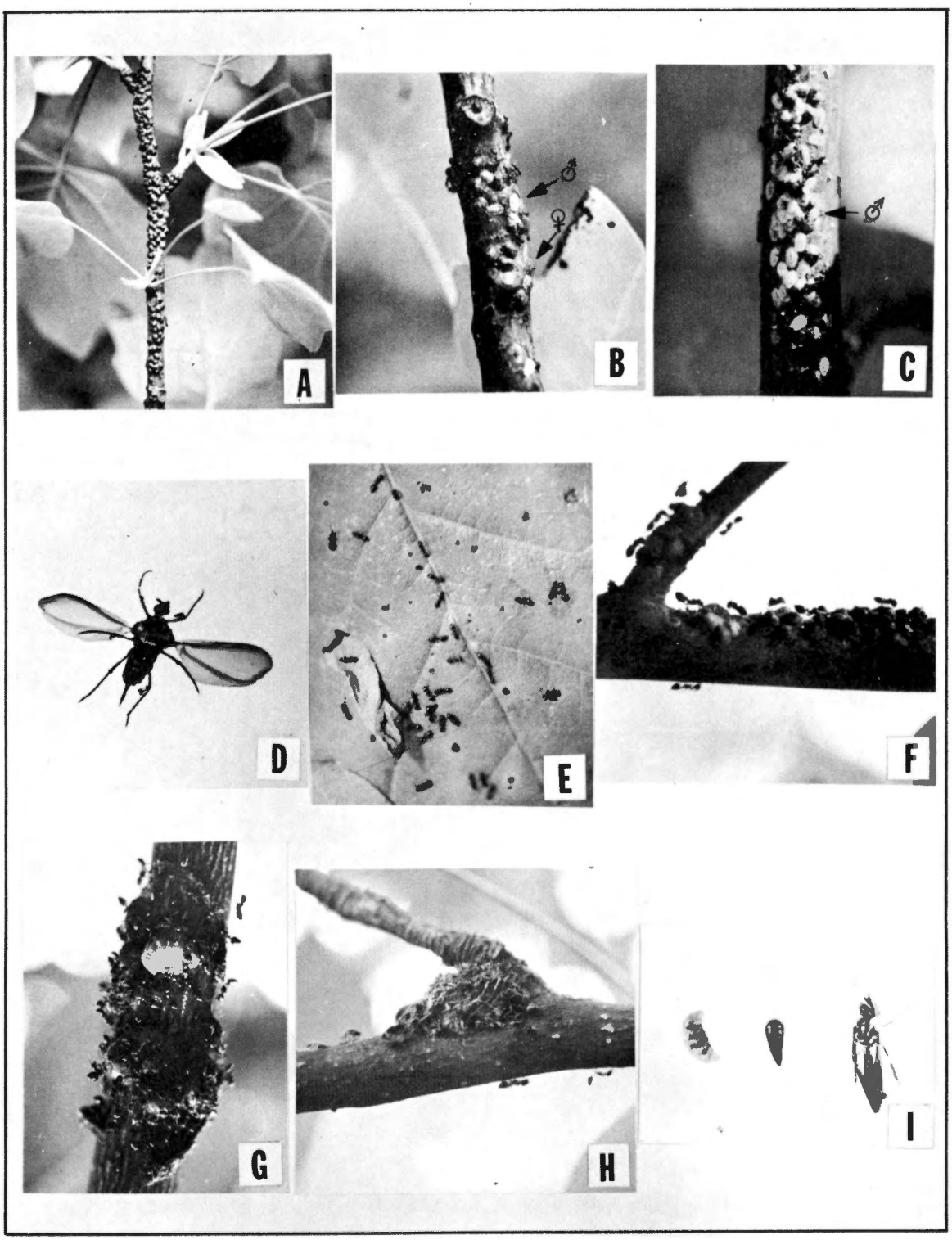
Photo E. Ants collecting honeydew which has fallen to lower leaves.

Photo F. Cremotogaster clara.

Photo G. Ant nests made of grass and debris.

Photo H. Completed ant nest.

Photo I. (Left to Right) Ocyptamus costatus (Say) larvae, pupae, and adult.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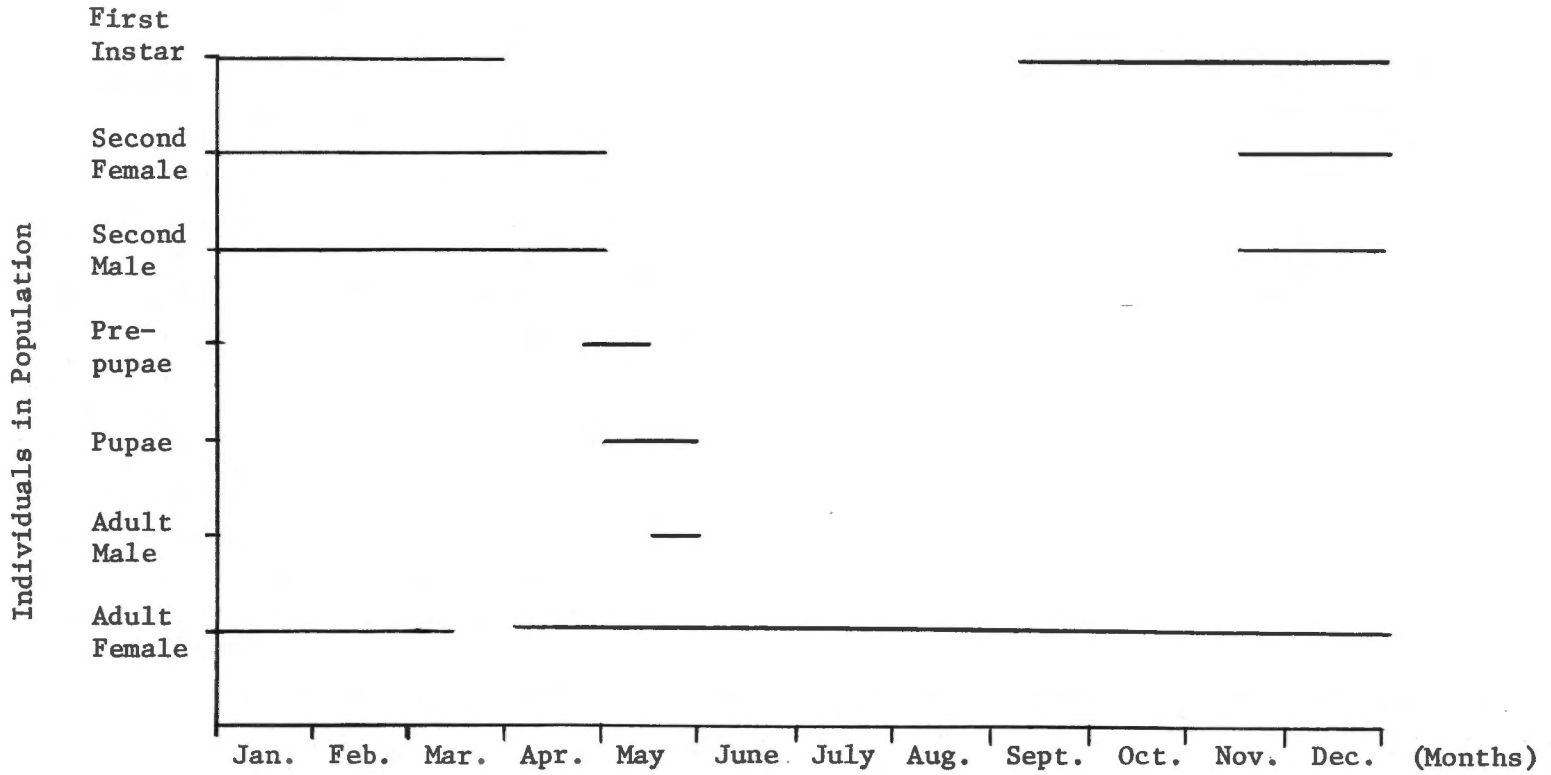


Figure 1. Seasonal history of Toumeyella liriodendri (Gmelin) on Lirodendron tulipifera L. in Tennessee, 1975-1976.

First instars had two distinct periods of development: a mobile stage during which they crawled for a few hours to ca. three days and a sessile stage during which they were attached to the host plant. Crawlers were present from mid-September until mid-December. Crawlers were oval, 0.5 mm long, 0.25 mm wide and were reddish-brown, 5.0 r/5/10 in color. Burns and Donley (1970) reported crawlers being dispersed by air currents for at least 30 meters. Once a suitable host was found they resumed their crawling activity in search for a site to settle. Crawlers established predominantly on the undersides of limbs less than 5 cm in diameter, at bases of buds, and around leaf scars. When a suitable site was found crawlers inserted their mouthparts into the plant tissue. Second instars lost functional legs with the first molt ca. two to three weeks after settling on the tree.

Tuliptree scales overwinter as both first and second instars with first instars present until mid-March. Second instars were oval, 1.0 mm long, 0.75 mm wide, and were reddish-purple, 5.0 r/3/2, in color. First and second instars were inactive through the winter and did not increase in size. Second instars molted to third instars in early April.

Honeydew was produced beginning in early March when feeding and growth were initiated. This period coincided with sap rise and budding of the yellow-poplar. Honeydew produced by the tuliptree scale fell to lower leaves, branches and the ground below the trees. It served as a medium for the growth of sooty mold fungi which inhibited photosynthesis by the plant and greatly reduced the aesthetic quality because

of its sooty appearance. The honeydew attracted many species of insects (Plate II-E). Krombein (1951) listed 93 Hymenopteran species that collected honeydew from the scales. Ten species of ants tending the tuliptree scale for honeydew were listed by Burns (1964).

In the present study four species of ants (Hymenoptera: Formicidae) were found tending scales and collecting honeydew. They were: Camponotus castaneus (Laterille); Crematogaster clara Mayr; Paratrechina melandri (Wheeler); and Monomorium minimum (Buckley). C. clara (Plate II-F) was the most abundant species. They afforded protection to tuliptree scales by aggressive behavior, and nest construction. Nests made of grass and debris (Plate II-G) were constructed about clusters of scales on yellow-poplar trees. The time required for nest completion varied with scale population to be enclosed and number of ants constructing a particular nest. These protective enclosures were built during summer and completed by mid-August (Plate II-H). Ant activity was observed to hinder oviposition by parasites. Bartlett (1961) found disturbance by ants resulted in 27.4% to 98.4% reduction in parasitization, depending on the parasite species. Burns and Donley (1970) reported a 50% increase in the number of scales surviving from spring to fall due to ant activity. Ants stroked the sides of scales with their antennae stimulating them to excrete honeydew. Once excreted the honeydew was held by the anal plates for a few seconds, during which the droplet was removed and swallowed by the ant. Crematogaster clara was observed biting marginal areas of scales causing bleeding. The ant swallowed this body fluid as if it were honeydew.

The presence of tuliptree scales can be determined by watching for ant activity on limbs and tree bases. Ants traveled along paths primarily on the undersides of limbs.

Two other insects found collecting honeydew were a picture-winged fly, Delphinia picta (Fabricius) (Diptera: Otitidae) and a wasp, Polistes sp. (Hymenoptera: Vespidae).

Natural control of the tuliptree scale at the collecting site in Knox County by parasites and predators was very successful over a three year period. The parasites reared from T. liriodendri were: Coccophagus sp. (Hymenoptera: Aphelinidae); Syntomosphyrum sp. (Eulophidae); and Ocyptamus costatus (Say) (Diptera: Syrphidae).

Ocyptamus costatus attacked third instar females from early May until late September. Of 304 adult females observed, 97.6% were parasitized. Scales parasitized by fly larva discolored dorsally becoming tan, 5.0 yr/6/4, as the parasite fed. Each parasitized female contained one parasite larva. Parasite larvae emerged and fell to the ground where they pupated and emerged as adults (Plate II-I, page 21).

Coccophagus sp. were reared from old dead adult females found clinging to limbs from the previous years infestation. Nineteen parasites were found pupating in one female. On May 7 they emerged in the laboratory. This parasite is new for T. liriodendri.

Two parasites found in close association with T. liriodendri were Aphidius sp. (Hymenoptera: Braconidae) and Tetrastichus sp. (Eulophidae). They were collected in early May and their importance is not known.

Predators collected in association with T. liriodendri included Laetilia coccidivora (Comstock) (Lepidoptera: Pyralidae), and four ladybird beetles (Coleoptera: Coccinellidae): Adalia bipunctata (Linnaeus); Chilocorus stigma Say; Cyoneda sp. and Hyperaspis signata (Olivier). Larvae (Plate III-A) of the predaceous moth L. coccidivora began feeding under the test of female T. liriodendri in mid-July. After consuming the initial scale the moth spun a web covering several other females (Plate III-B) which were consumed as needed. Burns and Donley (1970) reported L. coccidivora consuming 23 $\pm$ 7 mature female scales in the laboratory to complete its life cycle. This predator pupated (Plate III-C) in late fall and overwintered under scale tests. The adults (Plate III-D) emerged in the laboratory in mid-March.

The four coccinellids listed above were found in close association with T. liriodendri (Plate III-E) but were never seen consuming scales. Since these species are known to be predators it is assumed they play a role in controlling the tuliptree scale.

The mite, Tyrophagus sp. (Acarina: Acaridae) was found in close association with T. liriodendri feeding under old dead female tests. Baker and Wharton (1964) stated that the Acaridae except for one genus, Thyreophagus, are not predators or parasites.

Plate III. Biological aspects of Toumeyella liriodendri (Gmelin) and Chionaspis kosztarabi Takagi and Kawai.

Photo A. Laetilia coccidivora (Comstock) larva.

Photo B. Web spun by Laetilia coccidivora (Comstock) covering Toumeyella liriodendri (Gmelin).

Photo C. Laetilia coccidivora (Comstock) pupa.

Photo D. Laetilia coccidivora (Comstock) adult.

Photo E. Coccinellid in close association with Toumeyella liriodendri (Gmelin) on yellow-poplar.

Photo F. Fraxinus americana L.

Photo G. Chionaspis kosztarabi Takagi and Kawai.

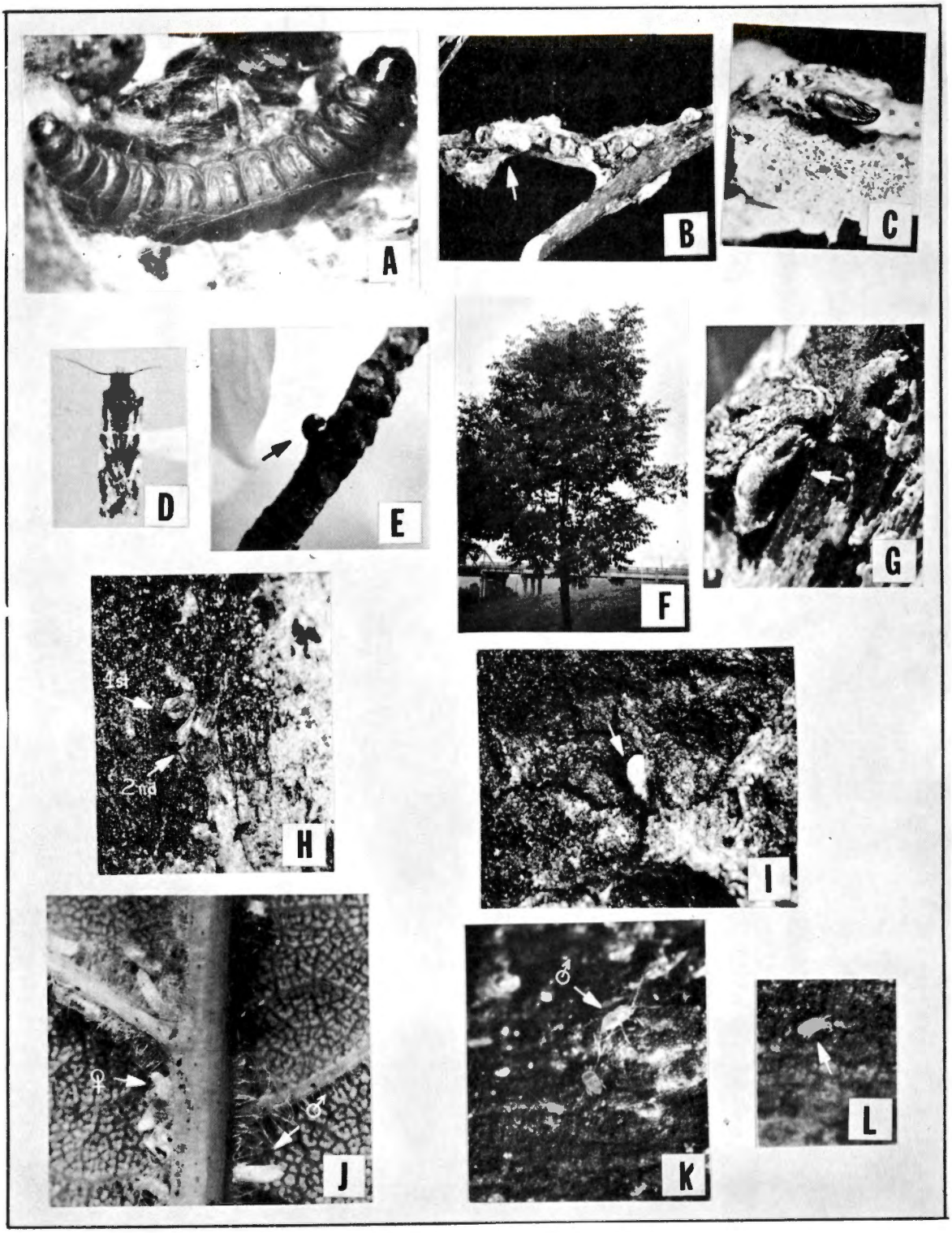
Photo H. Chionaspis kosztarabi Takagi and Kawai first and second instars.

Photo I. Chionaspis kosztarabi Takagi and Kawai adult male test in a crevice.

Photo J. Chionaspis kosztarabi Takagi and Kawai adult males and females in close association on Fraxinus americana L. leaf.

Photo K. Chionaspis kosztarabi Takagi and Kawai adult male searching for adult female to mate with.

Photo L. Mite, Amblyseius sp. found in close association with Chionaspis kosztarabi Takagi and Kawai adult females.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CHAPTER V

BIOLOGY OF *CHIONASPIS KOSTARABI* TAKAGI AND KAWAI

Chionaspis kosztarabi is a pest of *Fraxinus* sp. in Tennessee. This pest damages plants by sucking sap causing a loss of plant vigor. Heavy infestations may cause limb or even tree death.

Takagi and Kawai (1967) found *C. kosztarabi* to be a distinct species differing from *C. gleditsiae* Sanders and described the second instar male and adult female. No biological data was given. Willoughby and Kosztarab (1974) did the most comprehensive biological and morphological study of this species including illustrations of all stages.

Takagi and Kawai (1967) listed *C. kosztarabi* on *Fraxinus americana* L., *F. nigra* Marshall and *Fraxinus* sp. Beshear et al. (1973) reported this species on *Fraxinus* sp. in Georgia.

Biology

Biological studies of *C. kosztarabi* revealed it to be bivoltine and oviparous. Its primary host was white ash, *Fraxinus americana* L. (Plate III-F). This species overwintered as fertilized adult females.

Overwintering adult females were present until mid-June (Figure 2). They were found solitarily or in overlapping clusters on branches and twigs. The adult female test (Plate III-G) was oystershell-shaped, 2.7 (2.5-3.0) mm long, and 0.6 (0.5-0.8) mm wide. The tests varied in color from light gray to mottled white on branches. Minute yellowish first instar exuviae were located terminally. Adult females were pale

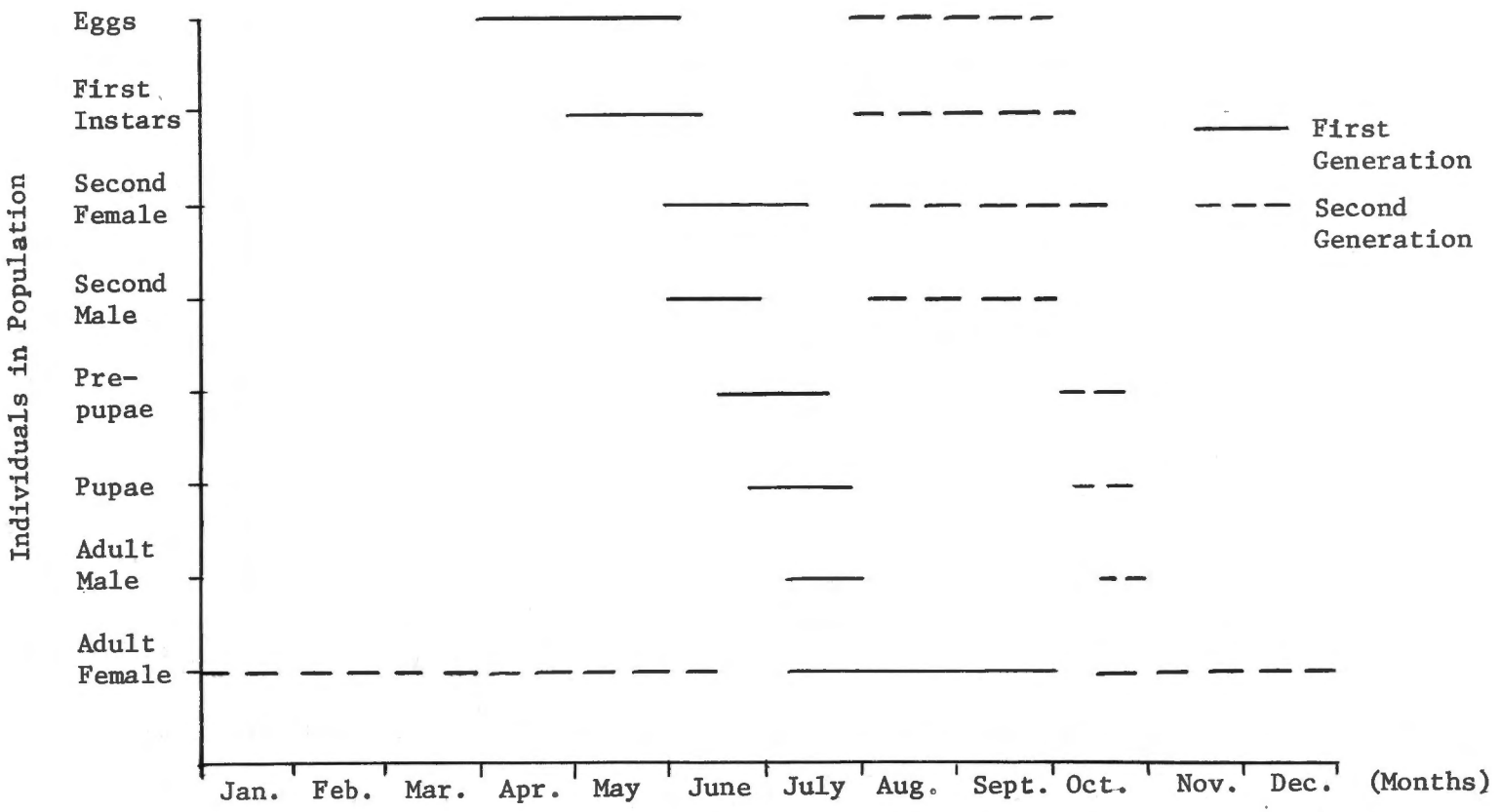


Figure 2. Seasonal history of Chionaspis kosztarabi Takagi and Kawai on Fraxinus americana L. in Tennessee, 1975-1976.

yellow in color, 5.0 y/8/8, and were spindle-shaped with laterally rounded segments. Ova formed in the abdominal region and gradually filled the entire ventral body region. Gravid females were initially orange, 7.5 yr/6/10, becoming reddish, 5.0 r/3/8, as their eggs developed. The average number of eggs laid by a female over a three week period was 101 (61-135). Eggs were initially deposited in the posterior portion of the test. However, as the number deposited increased, the female was gradually forced into the anterior portion of the test. The egg mass was several egg layers thick. Within one or two days after oviposition the females died. First generation eggs were deposited from late March to early June. Eggs were elliptical, 0.2 mm long, and 0.1 mm wide. They were orange, 10.0 r/6/10, with black eyespots. Each egg weighed 1.6×10^{-6} grams.

First generation crawlers emerged in late April and first instars (Plate III-H) were present until early June. They emerged from the chorion head first through a split in the anterior end and established on leaves, branches, beneath the adult female test or beneath old abandoned tests. Crawlers upon emergence were ovoid, ca. 0.2 mm long, 0.1 mm wide and were reddish, 5.0 r/6/10, in color. Crawlers placed on a white index card moved randomly at ca. 10 mm per minute.

First generation second instar females (Plate III-H) were present from late May to mid-July. Second instar males were present from late May to late June. Males and females could be distinguished by differences in test shape and color. Females on branches secreted a very thin white ventral wax sheet which adhered to the bark

and a dorsal test which varied in color from gray to mottled white. Females on leaves secreted a white dorsal and ventral test. Females enlarged their tests in length and width. Males on branches and leaves secreted white dorsal and ventral tests enlarging them only lengthwise.

Male tests were found isolated from females in cracks and crevices on branches (Plate III-I, page 28) and in close association with females on the undersides of leaves clustered along the midrib and veins (Plate III-J, page 28). They were more numerous on leaves than branches. Male tests were cylindrical, 0.5 mm long, 0.2 mm wide, tapering posteriorly to the exit flap which consisted of a slit at the posterior margin. Terminally located were minute yellowish, first instar exuviae. Males were oval with black lateral eyespots. Adult males were initially pale yellow, 5.0 y/8/8, gradually darkening to orange, 5.0 yr/7/10, at maturity.

Adult males were dimorphic with winged and non-winged forms present. Of a total of 68 adult males collected, 64 were non-winged and four were winged. Willoughby and Kosztarab (1974) reported that of a total of 98 pupae and adult males collected, 91 were non-winged and seven were winged.

Males were observed searching for females (Plate III-K, page 28) by randomly crawling over twigs and leaves until a suitable mate was located. They positioned themselves by backing toward the female test and probing it with the aedeagus until it entered the posterior slit. After the aedeagus was inserted, males held a stationary position for a few moments during mating before proceeding in search of another

female. Each male fertilized several females. One male was observed attempting to mate with a dead female from a previous generation.

First generation adult females were present from early July to early October. They were found most abundantly on branches and twigs; however, some first instars migrated to the underside of leaves where they aggregated along the midrib and veins.

Second generation eggs were deposited from late July to early October while crawlers emerged from late July to early October. Second instar females were present from early August to mid-October while second instar males were present from early August to early October. Prepupae and pupae were present from mid-October to late October while adult males were present from mid-October to late October. Second generation adult females mated with second generation males from mid-October to late October and overwintered as fertilized adults.

Many males and females infesting leaves were killed when white ash leaf drop began on October 15, 1975, and was completed by October 30, 1975.

One parasite, Marietta sp. (Hymenoptera: Eulophidae) was found parasitizing second instar females. These females molted to adults and died without producing eggs. Of 424 adult females observed 12.3% were parasitized. One parasite developed in each female.

One mite, Amblyseius sp. (Acarina: Phytoseiidae) (Plate III-L, page 28), was found in close association with adult females. This species was prevalent under tests when crawlers were emerging. They

were observed feeding on chorions left by crawlers after emergence and were plentiful under old female tests. This species was believed to be only a scavenger.

CHAPTER VI

BIOLOGY OF *PINNASPIS ASPIDISTRAE* (SIGNORET) WITH NOTES ON ITS CONTROL

The fern scale, *Pinnaspis aspidistrae*, is a pest of ornamentals in greenhouses and outdoors in Tennessee. This species causes plant damage by sucking sap causing chlorotic spots and a loss of plant vigor. Werner (1931) reported heavy infestations on ferns may ultimately cause the death of fronds.

The fern scale was first described by Signoret (1869) in Europe as *Chionaspis aspidistrae*. Cockerell (1896) referred to the species as *Chionaspis latus* from *Citrus* sp. Cockerell (1897) placed the species in *Hemichionaspis*. Later workers, Cooley (1899); Fernald (1903); MacGillivray (1921); and Werner (1931) agreed with Cockerell's classification. Lindinger (1912, 1913) considered *Pinnaspis* (Cook, 1892) and *Hemichionaspis* (Cockerell, 1897) synonymous and placed the species in *Pinnaspis*. Green (1916); Kuwana (1926); and Ferris (1934, 1937, 1947) agreed with this classification.

Biological studies were conducted by Essig (1915) and Werner (1931). Werner's study included the biology of each developmental stage.

Males have been widely reported (Comstock, 1916; Dietz and Morrison, 1916; Merrill and Chaffin, 1923; Kuwana, 1926; Werner, 1931; Ferris, 1937). Only the male test was described.

Control has been limited to greenhouse studies. Newell (1899) suggested using sulfur washes; resin washes; salt, lime and sulfur

washes; various soap solutions; fumigation with hydrocyanic gas; kerosene solutions; and tobacco solutions. Essig (1915) sprayed plants constantly with water when eggs were hatching for control. Werner (1931) stated that maintenance of high humidity suppressed large greenhouse populations.

Lilly turf, overwintering, infested with the fern scale was potted and placed in the greenhouse for chemical control studies (Plate IV-A). Before insecticidal application the developmental stages were determined. Plants were arranged in a randomized complete block replicated 10 times. Two leaves per plant infested with 10 scale insects were tagged with a white thread so these scales could be easily found again. Insecticides were applied as foliar sprays on August 2, 1975 and evaluated on August 7, 1975.

Biology

Biological studies of P. aspidistrae revealed it to be a multivoltine parthenogenetic species on lilly turf, Liriope spicata overwintering as adult females.

Overwintering adult females were present until mid-June (Figure 3). They were congregated from ca. 7 cm above soil level to just below soil level. The adult female test (Plate IV-B) was oystershell-shaped, 2.0 mm long and 1.3 mm wide. Tests were dark brown, 5.0 y/4/2, in color with minute yellowish first instar exuviae located terminally. Adult females were pale yellow, 5.0 y/8/8, in color and were spindle-shaped with laterally rounded segments.

Plate IV. Biological aspects of Pinnaspis aspidistrae (Signoret) and Quadraspidiotus juglansregiae (Comstock).

Photo A. Liriope spicata infested with Pinnaspis aspidistrae (Signoret) potted for chemical control studies in the greenhouse.

Photo B. Pinnaspis aspidistrae (Signoret) adult female with oystershell-shaped test.

Photo C. Pinnaspis aspidistrae (Signoret) first, second, and third instars.

Photo D. Parasite, Prospaltella sp., which parasitized Pinnaspis aspidistrae (Signoret) second instar females.

Photo E. Prospaltella sp. searching female test.

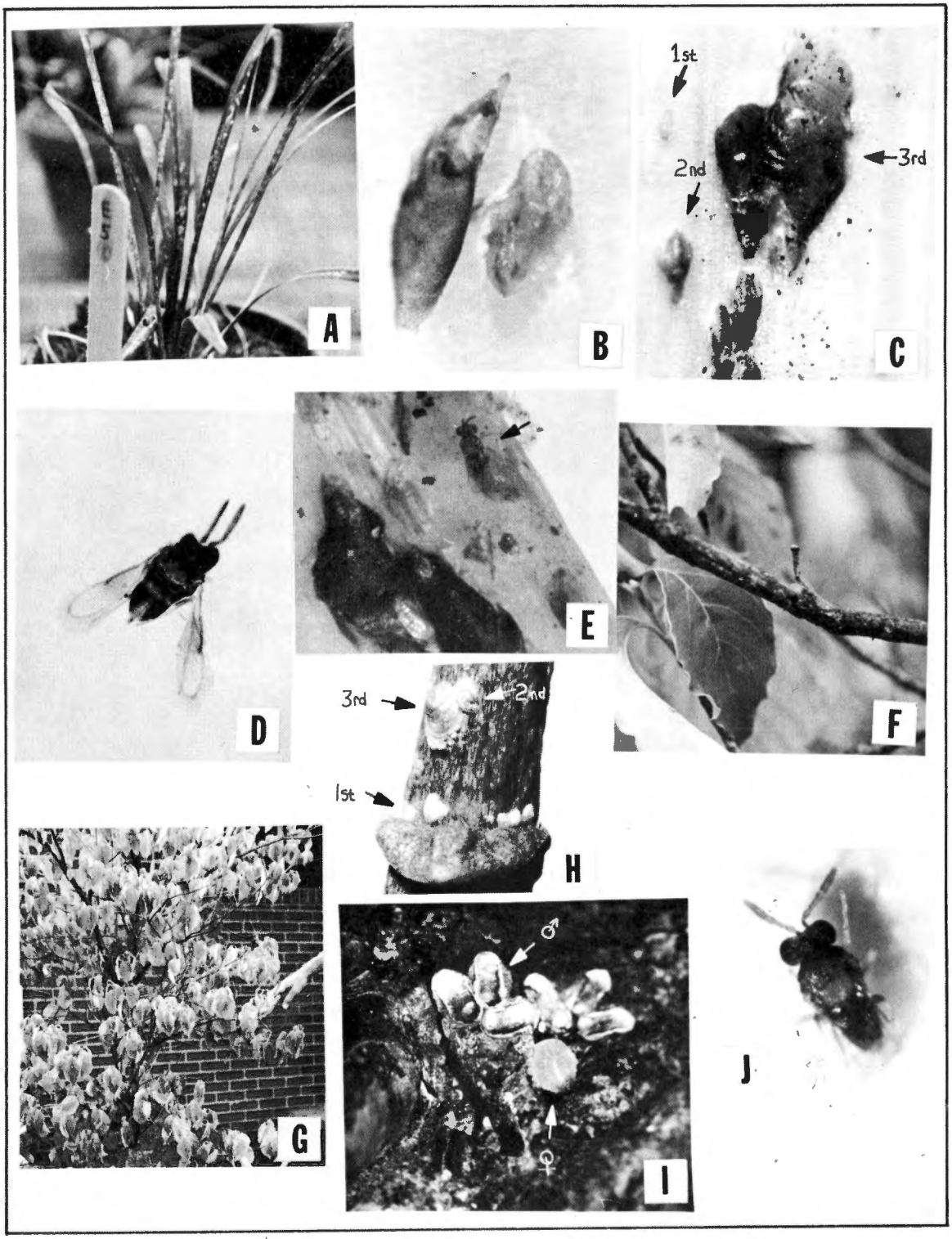
Photo F. Heavy infestation of Quadraspidiotus juglansregiae (Comstock) on Cornus florida L.

Photo G. Damage caused by heavy infestations of Quadraspidiotus juglansregiae (Comstock).

Photo H. Quadraspidiotus juglansregiae (Comstock) first, second, and third instars.

Photo I. Quadraspidiotus juglansregiae (Comstock) males and females in close association.

Photo J. Parasite, Prospaltella sp., found parasitizing Quadraspidiotus juglansregiae (Comstock).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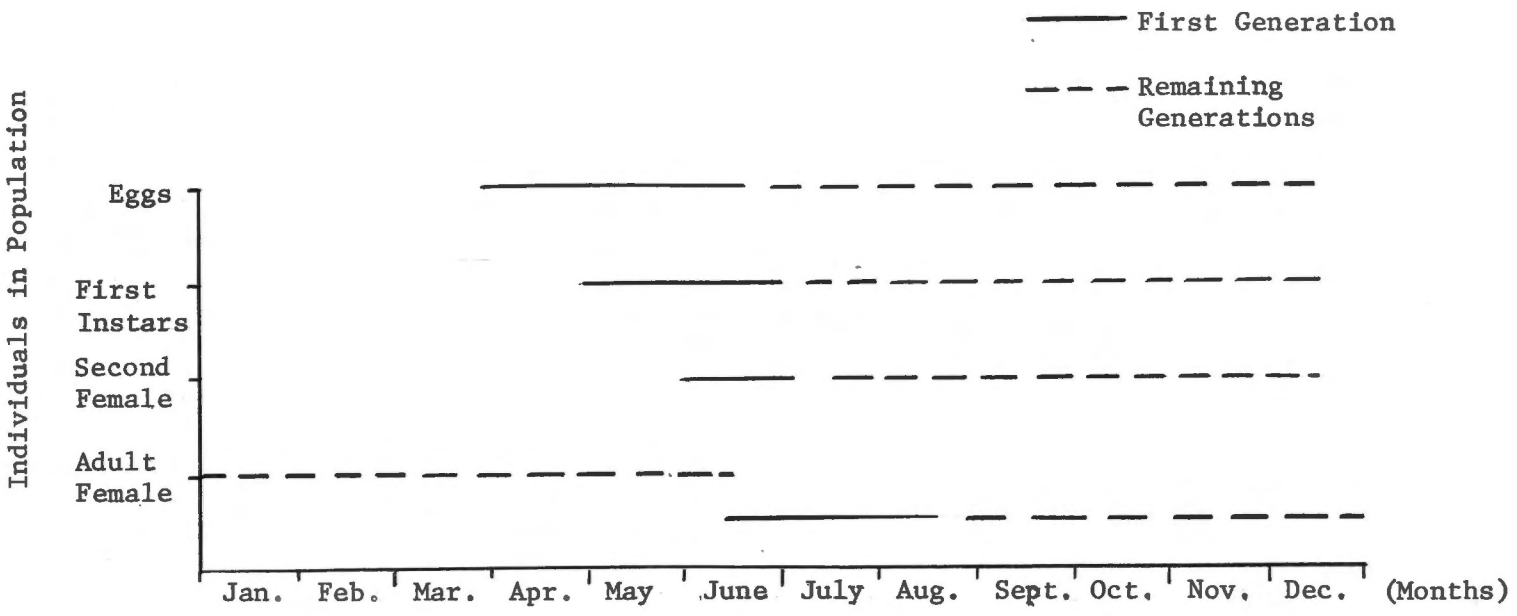

Figure 3. Seasonal history of Pinnaspis aspidistrae (Signoret) on Liriope spicata in Tennessee, 1975-1976.

This species was parthenogenetic reproducing by obligatory thelytoky, i.e., no fertilization occurred, resulting in a population exclusively of females. Ova formed in the abdominal region and gradually filled the body changing its color to a yellowish-red, 10.0 r/6/8. The average number of eggs laid by a female over approximately a four week period was 78(52-115). Eggs were initially deposited in the posterior portion of the test. As egg deposition continued the females were gradually forced into the anterior portion of the test by the egg mass which was several egg layers in depth. Females died within one or two days after oviposition.

First generation eggs were deposited from late March to mid June. Eggs were elliptical, 0.19 mm long and 0.10 mm wide. They were orange, 5.0 yr/7/6, with black eye spots. Each egg weighed 1.4×10^{-6} grams.

First generation crawlers emerged from mid-April and first instars (Plate IV-C) were present until mid-June. They emerged from the chorion head first through a split in the anterior end. Crawlers were ovoid, ca. 0.24 mm long, 0.12 mm wide, and were orange, 5.0 yr/7/10, in color. They established on leaves under the parental test or under old tests and were found solitarily scattered over the leaf surface. Crawlers placed ona white index card moved 12 mm per minute.

First generation second instar females (Plate IV-C) were present from late May to early July. The test color was tan, 5.0 yr/7/4. Second instar females had a pale yellow, 5.0 y/8/6, body color.

First generation adult females were present in mid-June and overlapped with second generation adult females in August. This species overwintered as adult females and were present until mid-June. The second and third generations overlapped and could not be distinguished from each other. There were three or four generations. Second generation eggs were deposited in late June and overlapped with third generation oviposition in August. Eggs were present until mid-December. Second generation crawlers began emerging in early July and overlapped with third generation crawler emergence in August. Crawlers and first instars were present until cold weather killed them in mid-December.

One parasite, Prospaltella sp. (Hymenoptera: Aphelinidae) (Plate IV-D) was found parasitizing second instars. The females molted to adults and a few individuals deposited an average of 17(12-23) eggs before death. These eggs matured and hatched. Of 305 females observed 26.8% were parasitized. Parasites overwintered as larvae and pupae which emerged in mid-May. This parasite searched for the female test feeling with its antennae (Plate IV-E) until a suitable host was found. It then turned 180° and probed the test with its ovipositor. Each individual parasitized many females. One parasite developed in each female. Parasites faced both anteriorly and posteriorly within the female body.

Control

Selected chemical insecticides were evaluated in greenhouse studies in 1975 to compare their efficiency in controlling P. aspidistrae on I. spicata.

Insecticides tested were orthene (0,5-dimethyl N-acetyl phosphoramidothiocate) 75W, carbaryl (1-Naphthyl methylcarbamate) 50W, and dimethoate (0,0-Dimethyl S-(N-methylcarbamyolmethyl) phosphorodithioate) 2E. All chemicals except orthene 75W were applied to stems and leaves to the point of runoff as 0.5% active ingredient sprays. Orthene 75W was applied as both a 0.5% and a 1.0% active ingredient spray. Only the first and second instars of development were present when the plants were sprayed.

Chemical treatments were applied on August 2. On August 7 the tagged leaves were removed in order to determine the number of living and dead scales microscopically.

Results and discussion. There was no significant difference between chemical treatments at the 5% level using Duncan's New Multiple Range Test (Table 2). There was a significant difference between all chemical treatments and the untreated check at the 1% level using Duncan's New Multiple Range Test. All chemical treatments gave effective control of both first and second instars of development.

TABLE 2

MORTALITY OF PINNASPIS ASPIDISTRAE (SIGNORET) BY FIVE INSECTICIDAL TREATMENTS, 1975

Treatment	AI %	Instar Mortality			
		First	Second	Third	Mean[1]
Control	--	3	21	--	2.4 a[2]
Orthene 75W	0.5	4	51	--	5.5 b
Orthene 75W	1.0	8	46	--	5.4 b
Dimethoate 2E	0.5	5	62	--	6.7 b
Carbaryl 50W	0.5	3	59	--	6.2 b

[1]Mean number dead for 10 replicates.

[2]Means followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

CHAPTER VII

BIOLOGY OF *QUADRASPIDIOTUS JUGLANSREGIAE* (COMSTOCK)

The walnut scale, *Quadraspidiotus juglansregiae* (Comstock), is a pest of flowering dogwood, *Cornus florida*, in Tennessee. This scale insect damages its host by sucking sap causing a loss of plant vigor. Heavy infestations (Plate IV-F, page 38) ruin the aesthetic value of trees and cause limb loss (Plate IV-G, page 38) or even tree death.

Comstock (1881) described the English walnut scale as *Aspidiotus juglan-regiae*. This species was referred to by Cockerell (1898) as *Aspidiotus fernaldi*, by Hunter (1899) as *Aspidiotus fernaldi albiventer*, by Parrott (1899) as *Aspidiotus fernaldi cockerelli*, by Cockerell (1902b) as *Aspidiotus glanduliferus* and by MacGillivray (1921) as *Furcaspis juglans-regiae*. Ferris (1938) studied the taxonomic status of the species and placed it in the genus *Quadraspidiotus*.

Investigations on this species have been primarily concerned with its taxonomic status. Morphological descriptions and illustrations were confined to the adult female and included only pygidal characters (Dietz and Morrison, 1916; Ferris, 1938; Kosztarab, 1963). Dekle (1965) compiled a comprehensive host list for the species.

Biology

The species *Q. juglansregiae* was bivoltine and oviparous on *C. florida* L. This species overwintered as second instar males and females.

Second generation adult females were present from early March to late July (Figure 4). They occurred solitarily or in overlapping clusters on bark over the entire tree. The adult female test was circular, slightly convex and 1.7 (1.5-2.0) mm in diameter (Plate IV-H, page 38). Tests were gray with a minute yellowish first instar exuviae located subcentrally. A very thin white wax sheet was secreted which adhered to the bark. Adult females were peariform, 1.2 mm long and 0.8 mm wide. Young adults were pale yellow, 5.0 y/7/8, in color while the body or gravid females changed slightly to a darker yellow, 5.0 y/8/8. Fecundity was not determined because crawlers hatched before all eggs were laid. No more than 20 eggs were found beneath any female. Within four to seven days after oviposition the females died.

First generation eggs were deposited from early May to mid-July. Eggs were elliptical, ca. 0.24 mm long and 0.10 mm wide. They were pale yellow, 5.0 y/8/6, with black eye spots forming after oviposition.

First generation crawlers emerged from early May to mid-July. They emerged head first through a split in the anterior end of the chorion. Crawlers settled under parental test, under old test, next to leaf scars and buds (Plate IV-H), on leaves, and over the entire trunk surface. Those establishing on leaves never matured. Crawlers upon emergence were ovoid, ca. .25 mm long, .12 mm wide. They were pale yellow, 5.0 y/8/6, in color. Crawlers placed on a white index card moved randomly at ca. 13 mm per minute.

First generation second instar females (Plate IV-H) were present from mid-June to early August. Second instar males were present from

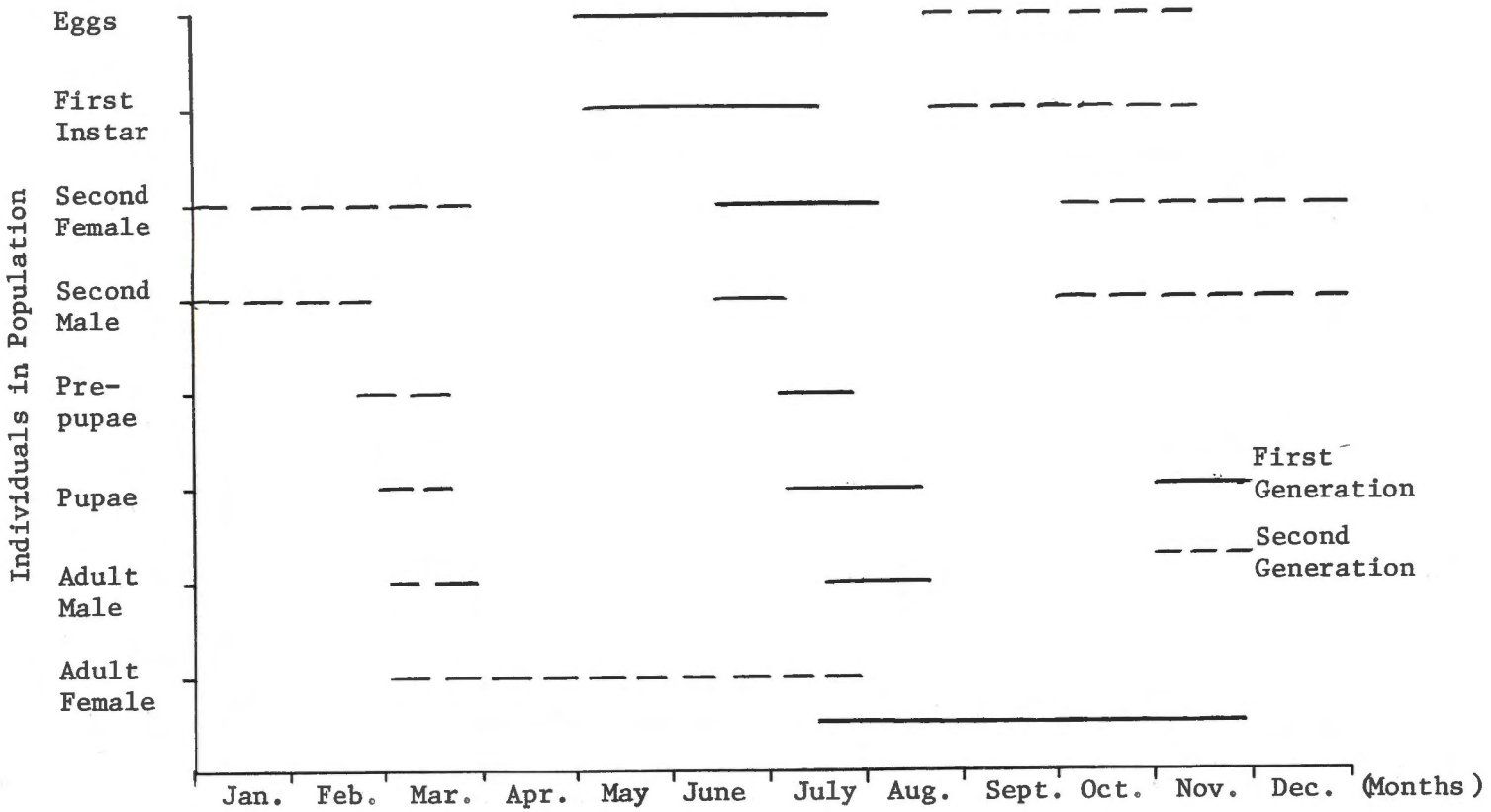

Figure 4. Seasonal history of Quadraspidiotus juglansregiae (Comstock) on Cornus florida L. in Tennessee, 1975-1976.

mid-June to early July. Sex could be distinguished when males began to elongate and develop rudimentary eyes in late June.

First generation males molted to prepupae in early July. Prepupae were present from early July to late July and pupae were present from mid-July to mid-August. Adult males emerged from mid-July to mid-August. Approximately eight to 10 days separated these male stages with adults living only a few hours.

Males were found solitarily or in close association with the female on bark (Plate IV-I, page 38) over the entire tree. There was a tendency for 9(6-12) males to establish in a cluster encircling 3(1-5) females with males facing the females.

Male test were oval, elongated, ca. 1.25 mm long, .75 mm wide, tapering posteriorly. They were gray with a minute yellowish first instar exuviae located terminally. A thin white wax sheet was secreted which adhered to the bark. Males were oval, elongated and pale yellow, 5.0 y/8/6, in color. Adult males were winged with wings held flat over the back.

First generation adult females were present from mid-July to late November. Second generation eggs were deposited from mid-August to late November. This species overwintered as second instars. Second instar females were present from early October to late March while second instar males were present from early October to late February. Prepupae were present from late February to mid-March while pupae were present from early March to mid-March. Adult males emerged from early March to late March and mated with the second generation females.

One parasite, Prospaltella sp. (Aphelinidae) (Plate IV-J, page 38) was found parasitizing second instar females. Once parasitized they turned dark orange, 5.0 yr/6/10, and never molted to adults. One parasite developed in each scale.

Mites found in close association with the walnut scale were: Camisia sp., Camasiidae Cheletomimus duosetosus Muma, Cheyletidae; and Tyrophagus sp., Acaridae. These mites were found beneath scale tests. Mites in the family Cheyletidae are known to be free-living predators while those in the family Acaridae are recorded as scavengers (Baker and Wharton, 1964). The status of the family Camisiidae is not known. One ladybird beetle, Chilocorus sp., Coccinellidae, was found preying on this scale insect.

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