The holly scale, Aspidiotus britannicus, Newst., is the most important insect pest of English holly in Oregon. It not only seriously injures the infested plants and detracts from their appearance but has caused considerable difficulty in the marketing of Christmas holly because of the danger of the insect attacking other plants or becoming established in other localities.

This insect was described by Robert Newstead in 1898 and had been found attacking holly in England in 1896. It has since been reported from Belgium, Cyprus, Island of Rhodes, Holland, Palestine, Transjordania Turkestan and in the United States from California, Indiana, Massachusetts, Michigan, New Jersey, New York, Oregon and Pennsylvania. The principal host plants appear to be English holly, bay trees, box and olives, although in Oregon it is of importance only on English holly.

The adult female scale covering is about 1.75 to 2 millimeters in diameter, oval or round with the exuviae central or a little to one side. The scale is dark brown in exposed positions and lighter on the under sides of the leaves. The insect is bright yellow in color with three pairs of lobes on the pygidium, the first two pairs having a trilobed appearance while the outer lobe has a notch on the distal side only.

The holly scale has but one generation a year in Oregon, the eggs are produced throughout the summer and each female appears to lay about a hundred eggs. Winter is passed in the immature stages; the males emerge in the spring, the last of April, 1933 and the last of March, 1934. The last molt of the female occurs shortly after the emergence of the males and egg production commences in the latter part of July 1933 and in the middle of May 1934, this season being considerably advanced. Reproduction continued until the early part of September in 1933.

Two chalcid parasites were found to attack the holly scale, Aphytis mytilaspis (How.) and Aspidiophagus citrinus, (Craw.), both determined by A.B. Gahan, United States Bureau of Entomology and P.H. Timberlake, Riverside Experiment Station, California. These parasites were found to be quite abundant in parts of Portland and appeared to be able to eradicate their hosts on holly grown in the greenhouse. They are both rather common parasites in the United States and other countries and are reported from a great many species of armored scale insects.
SOME OBSERVATIONS ON THE LIFE-HISTORY
AND BIONOMICS OF THE HOLLY SCALE,
ASPIDIOTUS BRITANNICUS NEWST.
IN OREGON

by

JAMES RICHARDSON ROAF

A THESIS
submitted to the
OREGON STATE AGRICULTURAL COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1934
# TABLE OF CONTENTS

Acknowledgements .............................................. 1

Introduction .................................................. 3

Production of Christmas Holly in the Pacific Northwest ..... 5

Amount of Holly Produced -- Uses of English Holly

Insect Pests of English Holly .................................. 8

Holly Leaf Miner -- Bud Moths -- Soft Scale Insect -- Minor Insect Pests of Holly

The Holly or Laurel Scale, *Aspidiotus britannicus*, Newstead 11

Description of Adult Insect by Newstead -- Additional Notes on Oregon Specimens -- Technique used for Mounting Specimens

Distribution and Host Plants of the Holly Scale ........... 16

Reported Distribution and Hosts -- Attempts to Infest other Plants with the Holly Scale -- Host Plants of the Holly Scale in Oregon

Losses Attributed to the Holly Scale in Oregon ............ 21

Injury to Infested Plants -- Effects on the Sale of Oregon Christmas Holly -- Quarantine Order Number 25 -- Treating Holly for Shipment

Life History of the Holly Scale ............................... 26

Adult Male Insects -- Eggs -- First Instar Larvae

Ecdyses or Molts -- Second Instar Larvae -- Third Instar Female -- Male Prepupae and Pupae

Ecology and Natural Control of the Holly Scale ............ 38

Low Temperature -- High Temperature -- Sunlight -- Rain -- Wind -- Viability of Insects on Cut Holly -- Insectivorous Birds -- Parasitic Insects -- *Aphytis mytilaspidis* -- *Aspidiotiphagus citrinus*

Bibliography .................................................. 49
TABLES AND ILLUSTRATIONS

Table 1. Some Localities and Host Plants from which Aspidictus britannicus has been reported. ........................ 17

Table 2. Some Interceptions of Aspidictus britannicus in California, as recorded in the Quarantine Division Reports in the Monthly Bulletin of the California State Commission of Horticulture, Sacramento, California. .......................... 18

Table 3. Number of Dead and Live Scale Insects found on Samples of Holly Treated at Commercial Dipping Plants in Portland. .......................... 25

Table 4. Seasonal Life History of Aspidictus britannicus through 1933 and part of 1934 .................................. 37

Plate I. Pygidium of holly scale, Aspidictus britannicus, greatly enlarged. ........................................ 52

Plate II. The holly scale, Aspidictus britannicus on English holly leaves. Upper left - female scale covers of the previous year; upper right - upper side of leaf, showing principally female scale covers; lower center - under side of leaf, showing principally empty male scale covers (x2). 53

Plate III. Fig. 1. Adult male holly scale underneath scale cover, ventral view. (x50) .............................. 54

Fig. 2. Scale cover of adult female holly scale. (x50) ................................. 54

Plate IV. Fig. 1. Prepupae of male holly scale. (x50) .................................. 55

Fig. 2. Adult of male holly scale. (x50) .................................. 55

Plate V. Fig. 1. Aspidiotiphagus citrinus pupae in holly scale insect. (x50) .................................. 56

Fig. 2. Aspidiotiphagus citrinus larvae in holly scale insect. (x50) .................................. 56

Plate VI. Fig. 1. Adult Aphytis mytilaspis. (x50) .................................. 57

Fig. 2. Adult Aspidiotiphagus citrinus. (x50) .................................. 57
ACKNOWLEDGEMENTS

In the preparation of this thesis assistance has been given by the entomology department at Oregon State College, the Oregon State Department of Agriculture, various producers of English holly, and others who are interested in this problem.

I am particularly grateful to Dr. Mote, head of the department of entomology for his suggestions and advice from the commencement of this work to the final preparation of the paper. Also, I am grateful to Kenneth Gray, Entomology Department, Oregon State Experiment Station, for the photographic work and for the interest he has shown in this problem. Other members of the Entomology Department who have assisted in many ways are: H.A. Scullen and W.J. Chamberlin, associate professors, B.G. Thompson, S.C. Jones, R.E. Dimick and W.D. Edwards, Oregon State Experiment Station, and Miss Velma Shattuck, Technician.

J.S. Wieman, State Horticultural Inspector, and other members of the Oregon State Department of Agriculture have assisted throughout this work in every way possible. Most of the information regarding the holly industry in Oregon and the quarantine, inspection and treatment of cut holly were furnished by Mr. Wieman. Also, a great deal of the material used in the life history studies was obtained through Mr. Wieman and others working out of the Portland office of the State Department of Agriculture.

I wish to take this opportunity to thank Mrs. Ralph Rawie for
the final typing of this thesis.

The Oregon holly growers, both commercial producers and those having but a few trees have been more than willing to help in this work, in fact, their assistance has been limited principally by my inability to make use of additional specimens of infested holly.
INTRODUCTION

The holly or laurel scale, Aspidiotus britannicus Newstead, is the most important insect pest infesting English holly, Ilex aquifolium Linn., in Oregon. As practically no information has been published regarding the life-history or control of the holly scale this preliminary work was undertaken with the intention of providing a basis for future work with this pest.

The losses caused by this scale insect will be discussed more fully but it might be mentioned here that these losses are three fold; first, the holly scale weakens, and may even kill, infested plants; second, the presence of this scale insect greatly depreciates the value of an infested plant both as an ornamental shrub and for Christmas decorations; and third, the efforts to control and restrict the distribution of this insect have caused considerable loss, inconvenience and expense to the growers and shippers of Christmas holly as well as to the states concerned.

Although many other difficulties are encountered in the commercial production of Christmas holly, the problems arising out of the establishment of this scale insect on English holly in Oregon are among the most serious that have confronted the Oregon holly industry. In fact, these problems constituted the main incentive for the organization of the Oregon Holly Growers Association in November of 1931. Requests for information regarding the control of this pest have come to the Oregon State Experiment Station from individual
growers, from the Oregon Holly Growers Association, from the Oregon State Department of Agriculture, from the County Agricultural Agents, and from D.B. Mackie, entomologist in charge of the division of entomology and pest control of the California Department of Agriculture. To answer these requests there has been practically no information available regarding the life history and control of the holly scale. Although it was assumed that this insect would be destroyed by the generally recommended scalicides, such as lime-sulfur and emulsions of the various petroleum products, almost nothing was known of the tolerance of the host plant to these substances and there is no published information regarding the life history of the holly scale in Oregon.

In this thesis the first step has been made in the accumulation of life history data which may be helpful in future work with either the life history or control of this insect pest.
Production of Christmas Holly in the Pacific Northwest

English holly has been grown for centuries in central and southern Europe and the British Isles. In North America, however, the production of holly, on a commercial scale at least, has been largely confined to the Pacific Northwest. This region, including southwestern British Columbia and the western portions of Washington and Oregon, appears to be the only portion of this continent that is particularly well suited to the culture of this plant. Although Zimmerman and Hitchcock (38) report that English holly has been grown successfully at Yonkers, New York, no large scale commercial plantings appear to have been attempted outside of the Pacific Northwest.

Amount of Holly Produced -- There is no available information regarding the extent of the commercial plantings of holly in the province of British Columbia although observations indicate that it is a very popular ornamental plant on Vancouver Island and the southwestern part of the mainland.

The results of investigations by the Washington State Department of Agriculture regarding the holly plantings in that state have been published by H.D. Locklin (21) as follows:

"According to figures of the State Department of Agriculture, there are in western Washington 32,215 holly trees
1 to 5 years old; 7,505 trees 5 to 10 years old; 1,800 trees
10 to 15 years old and 95 trees over 15 years old. These
figures refer to commercial trees only. . . .Roughly these
figures would indicate that there are now about 30 acres in
bearing, 100 acres that will be in bearing within the next 5
years and that there are now in nurseries enough trees to set
out 450 acres more. This lot of trees should, when in full
bearing, produce. . . .about 700,000 pounds or 350 tons of
holly annually."

According to correspondence with J.S. Wieman, Oregon State
Horticultural Inspector, the results of a recent questionnaire sent
out by the Oregon State Department of Agriculture indicate that the
value of the annual export of Oregon holly is approximately $50,000,
of which about 50 per cent is to California; while the value of the
holly sold within the state is estimated to at least equal this
amount. There are, roughly, 12,000 bearing trees in fifty commercial
plantings in Multnomah county alone and the number of trees in parks
and residences are beyond estimation. Although the commercial plant-
ings of English holly in Oregon appear to be more or less centralized
around Portland and Multnomah county, there are several other plant-
ings throughout the remainder of the western portion of the state.

Most of the English holly appears to be produced in the state
of Washington although a considerable portion of the industry is in
Oregon and also a large amount of cut holly is said to be exported
from British Columbia.
Uses of English Holly -- Although holly is chiefly grown for its ornamental and decorative value, the berries, leaves, bark and wood have been recommended and used for other purposes, among which may be mentioned the reputed medicinal value for the treatment of colic, intermittent fevers, jaundice and other ailments. Bird-lime, which is used for snaring small birds, may be obtained from the bark. Holly wood which is tough and hard, light colored, and of a fine texture, has been used in Europe for blocks and pulleys, timbering around chimneys and for the manufacture of mathematical instruments. Also, holly wood, either natural or stained as imitation ebony, has been used for inlaying work, snuff boxes and similar articles.

As ornamental plants, English hollies are well suited to use as solitary or grouped lawn trees or shrubs, or as hedges. They may be trimmed to almost any shape or allowed to grow in their natural form.

The association of English holly with religious rites and ceremonies is said to account for the name: The word "holly" probably has been derived from the word "holy". Today the greater part of the holly is cut and distributed during the month of December for use as Christmas decorations.

Most of the Christmas holly is distributed in the form of spray or cut holly. This product consists of the branches, with berries, and is cut, packed, and shipped without further manipulation. Holly wreathes are usually made up of branches having the most suitable leaves, and the berry cluster being attached separately.

There appears to be a growing demand for two, three and four
year old holly trees for Christmas decorations. According to Mr. Wieman, about a thousand such trees were sold during the season of 1933 and many more would have been sold had they been available.

These young trees are forced to produce berries by transplanting and other special cultural practices.

Insect Pests of English Holly

As English holly has been grown for centuries as a cultivated ornamental plant it would be expected to have a great many insect pests. This is not the case, however, probably because holly has not been grown as intensively as have many of the fruit trees and other cultivated plants. Only four serious insect pests of holly have come to the attention of the Oregon State Experiment station at Corvallis; these are: a holly leaf miner, probably Phytomyza ilicis Curtis; the oblique banded leaf roller, Cacaecia rosaceana Harris; an unarmored scale, either the soft brown scale, Coccus hesperidum Linn. or a closely related species, and the holly scale A. britannicus Newst.

Holly Leaf Miner -- No injury due to the holly leaf miner has been reported from Oregon although a holly leaf miner, Phytomyza ilicis, is reported to attack holly in British Columbia and the northern part of Washington. Coquillette (8) mentions specimens of this fly in the United States National Museum collection from Oregon and also reports collecting specimens in Alaska. Arthur Gibson (17) mentions this insect and, as no satisfactory control measures were known, he suggests the application of a sweetened poison bait spray
during the month of May, at which time the adults are flying. W. Downs (12) who has carried on experiments with the holly leaf miner, Phytomyza ilicis, recommends two applications of a 2 per cent nicotine dust to control the insects in the adult stage.

**Bud Moths** -- A bud moth was reported to have caused considerable damage in some of the commercial plantings of holly in Portland, Oregon. A few specimens were collected in the larval and pupal stages during the summer of 1933 and reared to the adult stage on holly. These specimens were determined by August Busck, Division of Identification and Classification of Insects, United States Bureau of Entomology, as the oblique banded leaf roller, Cacaecia rosaceana Harris. Another tortricid or bud moth, the holly bud moth, Rhopobota naevana (Hubner) var. ilicifolia, is reported by William S. Baker (2) as being the most serious pest of holly in Washington. This insect is also discussed by Gibson (17) and Downs (12). The most effective treatment appears to be a nicotine, lead-arsenate and soap spray in the following proportions: Lead arsenate, 3 ounces; whale oil soap, 4 ounces and nicotine sulfate (40%) 1 ounce; with three gallons of water. It is recommended that the trees be sprayed with considerable force with this material about the middle of May, followed by a second application about two weeks later when necessary.

**Soft Scale Insect** -- The unarmored or soft scale commonly found on holly and many other plants has occasionally been confused with the holly scale. It differs from *A. britannicus*, however, in being much larger and lacking the protective scale covering. There are other
distinguishing characteristics but these will be sufficient to differentiate between the two insects. No determinations have been received but this unarmored scale is probably the soft brown scale, *Coccus hesperidum* Linn. As this insect appears to be effectively controlled by light oil sprays on other host plants, Baker (2) suggests the application of a two or three per cent light oil, such as Volk. Two applications of this material rather effectively controlled a severe infestation of the soft scale on a holly tree on the Oregon State College campus. Any control measures developed for the control of the more serious holly scale should also be effective against the soft brown scale.

**Minor Insect Pests of Holly** -- Other insects mentioned by Baker as attacking English holly in Washington but doing very little injury are: at least one species of aphid; the obscure root weevil, *Sciopithes obscurus* Horn and the forest tent caterpillar, *Malacosoma disstria* Hubn. These insects have not been reported attacking holly in Oregon.

Dallimore (10) mentions black aphid on young shoots of English holly as well as the leaf miner *P. ilicis* and *A. britannicus*.

Essig (15) mentions five other scale insects and a flea beetle, *Epitrix cucumeris* Harris as attacking holly. The species of holly is not given in connection with any of these insects except the ivy or oleander scale, *A. hederae* Vallet. No records were found of any of these insects attacking English holly in Oregon, Washington or British Columbia.
Holly trees kept in the green houses at Oregon State College became infested with mealy bugs, probably the long tailed mealy bug, *Pseudococcus longispinus* (Targ). These appeared to be effectively controlled by washing the plants frequently with a strong force of water.

An infestation of thrips on holly in the Oregon State College greenhouse was reported by Robert Brown. They were later found on some of the holly kept in the greenhouse for holly scale studies. The thrips did not attack the mature leaves and caused very little injury. Specimens were determined by S.C. Jones, Entomology Department Oregon State Experiment Station, as the sugar beet thrips, *Heliothrips fumoralis* Reuter.

A species of psocid, probably the ten spotted psocid *Peripsocus californicus* Banks, is often very abundant on holly in Oregon. These insects do no injury to the holly other than the objectionable appearance of the egg masses and webs which they attach to the leaves. The fall rains, however, usually remove these before the holly is cut for Christmas decorations.

**Description of Adult Insect by Newstead** -- The holly or laurel scale, *Aspidiotus britannicus*, Newst. appears to be native to Europe and was first reported in England by Robert Newstead, F. E. S. (25) as *A. hederae* Vallot infesting holly at Teddington, near London. A note to explain this determination follows the original description of *A. britannicus* (26) by Newstead 1898.
"This is the species which was provisionally recorded (Ent. Mo. Mag. 1896 p. 279) under the name of *Aspidiotus hederæ Vall.* As the latter is now considered a var. of *A. nerii* Bouche, the Teddington insect appears to be an undescribed one and quite distinct."

In 1900, Mr. Newstead (27) published a more detailed description of this insect than occurred in the original description, including additional information regarding the control, host plants and distribution of the holly scale. To provide a basis for the comparison of the specimens collected here with the original specimens studied by Mr. Newstead a portion of this work is quoted from the Monograph of the British Cocoidae Volume I, Ray Society 1900, pages 117-119.

"**Puparium of the adult female (Pl. VIII figs. 8-12,** circular or approximately so; moderately convex. Color dusky ochreous, with a broad, smoky brown central zone. Exuviae central, or a little to one side; those of the larvae dark yellow, or dull orange yellow secretionary covering very thin, does not obscure either form or colour of the exuviae. Second secretionary covering, smoky brown, entirely covers the exuviae. Ventral scale very thin, remains attached to the leaf. The scales very readily fall from the food plant on the slightest disturbance of the contour of the leaf.

"**Diam 1.75 to 2 mm.**

"**Puparium of the female second stage (Pl. VIII fig. 9),** on the underside of leaf, fulvous, with the larval exuviae bright ochreous yellow, margins darker. In exposed situations on the leaves or branches the puparia are smoky brown with orange-ochreous exuviae.

"**Adult female (Pl. VIII fig. 10) translucent yellow; short ovate; with the segmentation very distinct; the pygidium well defined and produced.**
"Pygidium (Pl. VII, fig. 3) with four or five groups of circumgenital glands; the anterior group, rarely present, consists of 2-3; the anterior laterals from 7-10; the posterior laterals 7-8; the lateral groups in a narrow, more or less continuous series. Vaginal opening a little in front of the centre. Anal opening midway between the former and the apex. The groups of tubular spinnerets long; the longest extending almost to the base of the pygidium; connecting pores, towards the margin, occur on both dorsal and ventral surface. Margin of pygidium (Pl. XII, fig. 4) with three pairs of well-developed and widely separated lobes; the median and second pairs subequal, are notched or emarginate at the distal extremity of the margins, giving them a decided trilobed appearance; the third pair, smallest, usually have the inner lateral margins complete, the outer lateral margin irregularly notched. Plates comparatively short; median, second, and third pairs narrow, with one to three apical divisions; the first beyond the third lobe is also narrow, and serrated on its outer lateral margin; the two next very broad, have a deep central cleft; the posterior half simple or with a divided apex, the anterior half simple or with a divided apex, the anterior half strongly serrate on the outer lateral margin; the last plate is generally short and serrated in the same way as the previous ones. Two spines only were observed, the first opposite the third lobe, the second beyond the fringe; others probably exist, but my specimens were much too badly infested with fungi to ascertain this.

"Puparium of the male similar to that of the second-stage female; more or less circular, contracted form elongate or widely ovate. Colour bright pale fulvous. Larval exuviae central, usually bright orange-ochrious; secretory covering thin, smooth, and transparent, so that the color of the sublying exuviae shows through. The above description applies to such specimens as one finds upon the under sides of the leaves; those found in exposed situations are much darker, and often partly covered with a sooty deposit.

"Diameter 1 mm.

"Habitat: On holly (Ilex spp) at Teddington, near London (Dr. Masters), and the Royal Botanic Gardens, Kew (Nicholson). It also occurs at Kew on Ruscus hypoglossum.

"It was first discovered at the former locality in November, 1896, infesting a holly fence, and occurred in such swarms as to seriously injure the shrubs. Measures were taken to destroy the insects by the application of a paraffin emulsion,
which effectively killed the greater number of the insects on the upper surfaces of the leaves; but nearly all those on the under sides had escaped the application.

"Distribution: Mr. Cockerell informs me he has recently met with it in the United States, but I doubt if it is indigenous to that country."

Additional Notes on Oregon Specimens — The specimens collected here and studied by the author appear to differ from this description in that there are three squames between the second and third pair of lobes instead of two. The following quotation from Cockerell and Parrott (7) was sent in a letter from Theo. D.A. Cockerell:

"Aspidiotus britannicus" Newstead 1898 (Aspidiotus n.sp. Ckll. Bul. 6 Tech. Ser. Div. Ent. Sept. Agric., 1897, p. 12, fig. 9). The figure being original, from material supplied by Newstead, not 'after Newstead', as it was labelled without the author's knowledge)....

In this figure there are three squames shown between the second and third lobes as in the specimens observed here. The color of the exuvia and scale covering appears to be affected by exposure.

The male puparium or scale cover of the specimens studied (Pl. III fig. 1) here appear to be slightly more elongated than those described and illustrated by Mr. Newstead. Also, Mr. Newstead describes but two spines on the pygidium, adding, however, that his material was too badly infested with fungi to distinguish more, but he believed them to be present. Specimens here show five pairs of spines on the pygidium, a spine at the base of each lobe and two
pairs on the margin in front of the lobes as is shown in the drawing of the pygidium (Pl. I).

The terms for the parts of the pygidium as described by Newstead (27) have been used here as a matter of convenience although some of these terms have not been accepted by later authorities. The spines for example, should probably be called spine-like setae; and the puparium, the scale cover.

Technique used for Mounting Specimens -- The most satisfactory method found for mounting the adult female scales was a technique obtained from H.A. Scullen, entomology department, Oregon State College. This method was used as follows:

1. Place the specimens in KOH (10%) in a small test tube which was placed in boiling water until the specimens were clear, that is, until almost all of the yellow color had disappeared.

2. Wash the specimens in several changes of distilled water.

3. Place in acid fuchsin until the specimens become considerably darker than the surrounding liquid.

Formulae for acid fuchsin stain:

- Acid fuchsin crystals .5 grams
- 10% solution of hydrochloric acid 25.0 c.c.
- distilled water 300.0 c.c.
4. Remove to 95% alcohol for about ten minutes.

5. Mount in diaphane.

The exuviae impregnated in the scale covers were found to show up clearly when the covers were cleared somewhat in glacial acetic acid, stained in acid fuchsin stain and run through acetic acid two parts, and clove oil one part, and a second solution containing equal parts of acetic acid and clove oil. The specimens were left in each of these solutions for about ten minutes and mounted in diaphane. The photograph (Pl. III fig. 2) was made from a scale cover prepared by this method. This technique which is described by H. Britten, (5) was also used in the preparation of the male scales and the two chalcid parasites, both with and without staining.

Distribution and Host Plants of the Holly Scale

In a further discussion of this scale insect by Newstead (28) he states that: "It appears not to be confined to holly, and should therefore be regarded with suspicion, and not be allowed to establish itself on fruit trees. Coccids so often prove omnivorous, or nearly so, that it is advisable at all times to guard against possible attack."

**Reported Distribution and Hosts** -- This insect appears to be rather widely distributed now and has been recorded from a number of host plants. The available information regarding its distribution and host plants is presented in Tables I and II.
<table>
<thead>
<tr>
<th>Reported from</th>
<th>Host</th>
<th>Date</th>
<th>Reported by</th>
</tr>
</thead>
<tbody>
<tr>
<td>England</td>
<td>English holly</td>
<td>1896</td>
<td>Newstead (25)</td>
</tr>
<tr>
<td>England</td>
<td>English holly</td>
<td>1898</td>
<td>Newstead (26)</td>
</tr>
<tr>
<td>Salem, Oregon</td>
<td>English holly</td>
<td>1898</td>
<td>Cordley (9)</td>
</tr>
<tr>
<td>Salem, Oregon</td>
<td>English holly</td>
<td>1899</td>
<td>Cockerell and Parrott (7)</td>
</tr>
<tr>
<td>England</td>
<td>Holly</td>
<td>1900</td>
<td>Newstead (27)</td>
</tr>
<tr>
<td>U. S. A.</td>
<td>Ruscus hypoglossum</td>
<td>1900</td>
<td>Newstead (28)</td>
</tr>
<tr>
<td>England</td>
<td>Holly</td>
<td>1902</td>
<td>King (20)</td>
</tr>
<tr>
<td>Salem, Oregon</td>
<td>English holly</td>
<td>1899</td>
<td>Newstead (27)</td>
</tr>
<tr>
<td>Boston, Mass.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>England</td>
<td>Holly</td>
<td>1903</td>
<td>Fernald (16)</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>R. hypoglossum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>California</td>
<td>English Laurel</td>
<td>1915</td>
<td>Essig (14)</td>
</tr>
<tr>
<td>San Francisco</td>
<td>Holly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bay region</td>
<td>Butcher's broom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indiana</td>
<td>Bay trees in greenhouse</td>
<td>1915</td>
<td>Dietz &amp; Morrison (11)</td>
</tr>
<tr>
<td>New Jersey</td>
<td>Bay from Belgium</td>
<td>1914</td>
<td>Weiss (35)</td>
</tr>
<tr>
<td>New Jersey</td>
<td>Bay (in greenhouse)</td>
<td>1916</td>
<td>Weiss (36)</td>
</tr>
<tr>
<td>U. S. A.</td>
<td>Box Bay trees</td>
<td>1918</td>
<td>Pierce (29)</td>
</tr>
<tr>
<td>Connecticut</td>
<td>Greenhouses</td>
<td>1923</td>
<td>Britton (5)</td>
</tr>
<tr>
<td>Turkestan</td>
<td>Eleagnus hortensis</td>
<td>1923</td>
<td>Arkhangelskaya* (1)</td>
</tr>
<tr>
<td>Transjordania</td>
<td>Olea europaea</td>
<td>1923</td>
<td>Bodenheimer* (3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South of the Rhine Valley</td>
<td>Olea</td>
<td>1924</td>
<td>Wunn* (37)</td>
</tr>
<tr>
<td>Palestine</td>
<td></td>
<td>1924</td>
<td>Bodenheimer* (4)</td>
</tr>
<tr>
<td>Island of Rhodes</td>
<td>Ligustrum</td>
<td>1926</td>
<td>Teodoro* (34)</td>
</tr>
<tr>
<td>Cyprus</td>
<td>Carob, Ceratonia siligua</td>
<td>1928</td>
<td>Morriss (24)</td>
</tr>
</tbody>
</table>

*The original publications not being available, the data was obtained from the Review of Applied Entomology.*
TABLE 2

SOME INTERCEPTIONS OF A. BRITANNICUS IN CALIFORNIA AS RECORDED

IN THE QUARANTINE DIVISION REPORTS IN THE MONTHLY BULLETIN OF THE

CALIFORNIA STATE COMMISSION OF HORTICULTURE, SACRAMENTO, CALIFORNIA

<table>
<thead>
<tr>
<th>Source</th>
<th>Host</th>
<th>Intercepted</th>
<th>Vol. No., Page of Bulletin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>Laurus sp.</td>
<td>San Francisco</td>
<td>June 1912, I, 12:607</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>San Francisco</td>
<td>May 1913, II, 7:599</td>
</tr>
<tr>
<td>Holland</td>
<td>Bay</td>
<td>San Francisco</td>
<td>Dec. 1913, III, 2:94</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>Los Angeles</td>
<td>Nov. 1914, IV, 1:55</td>
</tr>
<tr>
<td>Pa</td>
<td>Palms</td>
<td>San Francisco</td>
<td>June 1915, IV, 8:401</td>
</tr>
<tr>
<td>Michigan</td>
<td>Bay</td>
<td>Los Angeles</td>
<td>Oct. 1915, IV, 12:576</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>San Francisco</td>
<td>Nov. 1915, V, 1:24</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>Los Angeles</td>
<td>Nov. 1915, V, 1:24</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>San Diego</td>
<td>Jan. 1916, V, 3:123</td>
</tr>
<tr>
<td>New York</td>
<td>Orchids</td>
<td>San Diego</td>
<td>Aug. 1916, V, 10:392</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>San Francisco</td>
<td>Nov. 1916, VI, 1:36</td>
</tr>
<tr>
<td>Holland</td>
<td>Bay</td>
<td>San Francisco</td>
<td>Dec. 1916, VI, 2:66</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>Los Angeles</td>
<td>Dec. 1916, VI, 2:67</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>San Diego</td>
<td>Dec. 1916, VI, 2:67</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>Los Angeles</td>
<td>June 1919, VIII, 7:432</td>
</tr>
<tr>
<td>Belgium</td>
<td>Bay</td>
<td>Los Angeles</td>
<td>Sept. 1919, VIII, 9:547</td>
</tr>
<tr>
<td>New York</td>
<td>Bay</td>
<td>Los Angeles</td>
<td>Nov. 1919, IX, 12:250</td>
</tr>
<tr>
<td>New Jersey</td>
<td>Bay</td>
<td>San Francisco</td>
<td>May 1920, IX, 7:301</td>
</tr>
</tbody>
</table>

Attempts to Infest other Plants with the Holly Scale — A few holly plants infested with the holly scale were placed in the greenhouse at Oregon State College in the spring of 1933. It was expected that these scales would increase and supply abundant material for attempts to establish this insect on other hosts during the winter. On examining these trees in September, however, no live scales could be found. Apparently the chalcid parasite, Aphytis mytilaspis (How.) had destroyed the entire stock.
Some infested seedlings were potted and placed in the greenhouse November 28, 1933. Although the scale insects on these plants were quite heavily infested with the parasite mentioned above and also with _Aspidiotiphagus citrinus_ (Craw.), a few reached maturity. The males emerged during the latter part of December and the first crawling young were found on January 30, 1934.

The scale insects on the lightly infested leaves and the stems were destroyed with their parasites and the more heavily infested leaves were placed in cylindrical, cardboard mailing boxes. Glass vials were inserted into holes cut in the sides of these boxes for the purpose of collecting the young scale insects. A large number of the adults of both of the parasites were obtained by this method and the young holly scales also proved to be positively phototropic.

A few of these newly hatched larvae were removed from the glass vials with a fine camel hair brush and placed on the leaves of English holly. An infestation was started in this manner which, it is hoped, will remain free of parasites and be available for future use.

Through the assistance of Robert Brown, senior in the department of landscape architecture at Oregon State College, the following plants were obtained: Japanese holly, _Ilex cornuta_; _I. integracerena_; two _Ilex_ species at present unknown, and labeled as _Ilex_ F. P. I. 91255 and X, and a seedling Ponderosa lemon.

The newly hatched larvae of the holly scale were placed on these
plants in the same manner as they had been placed on the English holly and as a further check a few were placed on English holly leaves at each time attempts were made to infest these other plants. In each case the larvae were not considered unless they appeared to be uninjured and were observed to crawl actively over the leaves of the plant on which they had been placed.

On February 9, ten larvae were placed on the Japanese holly. None of these could be found on the following day and five more were added. On February 15, twelve more larvae were placed on this plant. At least twenty-seven live, active larvae were placed on this plant, none of which became established.

The two unknown species of holly were treated on February 15 with twelve larvae apiece. The scale insects were apparently unable to infest these plants also.

Ten larvae were placed on the Ponderosa seedling on February 9. The following day two of these were found to be still crawling over the surface of the leaves. On February 14, one dead larvae was found on a leaf. Twelve more larvae were placed on this plant on February 15, none of which were ever found again.

In practically every instance when uninjured larvae were placed on the original host they became established without traveling more than a few inches at the most. Frequent observations were made of the other plants until April and no scale insects were found to have become established. While these unsuccessful attempts to establish the holly scale on other plants do not prove that it is unable to
attack these plants, they would seem to indicate that these plants are not as satisfactory hosts for *A. britannicus* as is the English holly.

It is regrettable that circumstances delayed experiments of this nature and that there were so few larvae and plants available when these observations were made. Plans have been made, however, for further work of this nature during the coming summer.

**Host Plants of the Holly Scale in Oregon** -- Although the holly scale is well established on English holly in Portland, it does not appear to be a serious pest on any other plants. Mr. Wieman reports having found the holly scale attacking English laurel or bay trees which were adjoining or near infested holly trees. This scale insect however, has not been reported as a serious pest of English laurel in Oregon.

Mr. Wieman also collected scale insects on box, *Buxus sempervirens*. On microscopical examination these scale insects appear identical to those attacking holly.

**Losses Attributed to the Holly Scale in Oregon**

*A. britannicus* is the most important insect pest of holly in Oregon and appears to have caused greater losses than all of the other insect pests and diseases of English holly in Oregon.

**Infested Injury to Plants** -- A severe infestation of the holly scale is capable of seriously weakening and devitalizing a tree and would, if unchecked, probably result in the death of the host. One
such tree was found in Portland, Oregon, in the summer of 1933. The 
foliage was noticeably sparse and lacked the deep green luster of a 
healthy plant. Many of the branches were apparently dead and there 
was but little new growth on the branches that were still alive. 
This tree was quite successfully treated with a calcium cyanide dust 
and most of the dead wood was removed. A fairly good growth was 
oberved in the spring of 1934 and the tree has apparently recovered 
from the attack.

Aside from the pathological effects of the holly scale it de-
tracts from the appearance of the infested plant, causing it to be 
not only undesirable but often unsalable for either Christmas decora-
tions or for ornamental plants. Even if the scales are removed from 
the leaves, stems and berries the light colored spots will remain on 
the host for some time. These light colored spots found underneath 
the insects may be caused by their feeding but are more likely the 
result of the scale protecting a portion of the plant from the sun-
light.

Effects on the Sale of Oregon Christmas Holly — There is a 
third feature of this insect pest that has probably been the cause of 
greater economic loss than the direct effect on the holly tree. The 
neighboring states, particularly California, have had so many serious 
entomological problems develop from the introduction of exotic in-
sects that it is but natural that the authorities should be sus-
picious of the scale insects attacking holly. Although the restric-
tions have principally affected the holly being sent to California
they have had rather serious and far reaching effects on the holly industry in Oregon. As the California market takes about fifty percent of the holly shipped out of Oregon, this portion of the industry has been directly affected. Furthermore, it would seem quite logical to assume that holly buyers in other states and countries would be inclined to discriminate against infested Christmas holly from Oregon.

Quarantine Order Number 25 -- Although the holly scale has been present in a few parts of Oregon for many years, no real difficulty was experienced with shipment of Christmas holly until the season of 1931. By this time the scale insect had apparently extended its distribution in Oregon and was being intercepted on Oregon holly shipped to California. Because of the danger of this insect attacking other California plants, Oregon holly was barred from California during the latter part of 1931. This embargo was removed for the season of 1932 for holly tested according to Quarantine Number 25 of the Oregon State Department of Agriculture.

This Quarantine order which went into effect for the season of 1932 provided that all holly intended for shipment should be dipped unless from trees inspected during the previous summer and found free of scale, or if found to be infested, the trees must have been successfully treated and found free of live scale insects at a further inspection prior to the cutting of the holly.

Treating Holly for Shipment -- The dipping solution recommended and required at that time consisted of formalin and nicotin sulphate
(40%), dissolved in a soap solution, 16 pounds of soap, one fifth of a gallon of nicotine sulphate and one fifth of a gallon of formalin being used to each hundred gallons of water. The instructions were that the holly be dipped for ten minutes, allowed to drain for fifteen minutes and then rinsed in clear water. It was further specified that the solution be maintained at a temperature of at least 60°F.

This material and treatment is said to have been demonstrated to the satisfaction of the California authorities at Sacramento by J.B. Kelly, of the Mount Hood Holly Orchard, Portland, who appears to be the author of this method of treating holly.

At the request of the Oregon State Department of Agriculture, the Entomology Department of Oregon State College carried on some very limited tests of this material and examinations were made of infested holly samples that had been treated at commercial dipping plants in Portland using this method. (See Table 3, page 25.)

Also, during the latter part of December live scale insects were intercepted in California on holly from Oregon and shipments estimated by Mr. Wieman at a value of approximately one thousand dollars were rejected by California authorities because of the presence of live scale insects.

It is not known why the insects survived this treatment during December when they were apparently killed by this same method earlier in the season. There may have been some fault with the methods used at some of the dipping plants or possibly the unusually low tempera-
### TABLE 3

**NUMBER OF DEAD AND LIVE SCALE INSECTS FOUND ON SAMPLES OF HOLLY**

**TREATED AT COMMERCIAL DIPPING PLANTS IN PORTLAND**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dead</td>
<td>alive</td>
<td>dead</td>
<td>alive</td>
<td>dead</td>
<td>alive</td>
<td>dead</td>
<td>alive</td>
</tr>
<tr>
<td>1</td>
<td>42</td>
<td>8</td>
<td>42</td>
<td>8</td>
<td>28</td>
<td>2</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
<td>18</td>
<td>39</td>
<td>10</td>
<td>11</td>
<td>2</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>45</td>
<td>5</td>
<td>49</td>
<td>1</td>
<td>73</td>
<td>2</td>
<td>97</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
<td>14</td>
<td>19</td>
<td>6</td>
<td>7</td>
<td>2</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>26</td>
<td>43</td>
<td>7</td>
<td>25</td>
<td>2</td>
<td>47</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>17</td>
<td>33</td>
<td>31</td>
<td>19</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

- Leaves dried.
- No insects left.

1. Dipped December 16, 1932 by Kern Park Floral Company
2. Dipped December 16, 1932 by Murphy Schall Company
3. Dipped December 16, 1932 by Mrs. Hathe
4. Dipped December 19, 1932 at the Express Depot
5. Dipped December 19, 1932 by Hink Dipping Plant
tures prevailing at that time may have decreased the effectiveness of the solution and increased the tolerance of the insects.

During the following season, 1933-34, the holly was dipped in oil emulsions and apparently very few if any live scale insects were intercepted on holly treated in this manner, although some of the oils used caused considerable leaf injury.

Life History and Development of the Holly Scale

*A. britannicus* has but one generation a year on holly in Oregon. This might be a further indication that the species is of British origin, as, according to A.D. Imms, (19) "The indigenous British Coccids are univoltine...". During the winter the scales are in the partially grown stage; the adult males emerge in the early spring, in the latter part of March or April; egg laying commences about the early part of July and continues for about two months.

**Adult Male Insects** -- The adult males (Pl. IV fig. 2) are about 1.5 mm. long and are of the same yellow color as the females. A dark band, however, extends across the thorax between the bases of the wings and the halters. They have but one pair of wings, the hind wings being reduced to a pair of club-shaped halters, each halter having a bristle that fits into a pocket or fold of the wing on the same side. By this means, the halters probably aid in flight. The wing venation is greatly reduced, the radius and medius are unbranched veins joined at the base. The subcostal vein is present although considerably reduced. The wings are held flat and parallel
with the body when at rest. The legs are of the type usually found on insects but have only one tarsal segment, which bears a single claw. The posterior end of the body is terminated with the stylus. This spine-like genital sheath encloses the aedeagus and apparently enables the male to fertilize the female underneath the scale cover.

In 1933 the males emerged during the last of April, and in 1934 they emerged during the latter part of March. The late emergence in 1933 was probably due to the relatively cold rainy spring following a rather severe winter. An early spring, following a mild winter would account for the earlier emergence in 1934.

In view of the variation in seasonal life history it would probably be more accurate and valuable to correlate the life cycle of the pest with that of the host. For example, the emergence of the males in 1934 appeared to coincide with the first appearance of the holly flowers and the last molt of the females with the opening of the leaf buds and the commencement of the new growth. The hatching of the first eggs could be compared with the amount of new growth. Observations of this nature should be made over a period of many years, however, and on a great many of the varieties of English holly before such comparisons could be presented with any degree of accuracy.

Approximately a hundred male scales were obtained from holly that was cut and placed at room temperature, in cardboard boxes, on February 16, 1934, the adults emerging during the first half of March. It was noticed that the males were found in the vials, in-
serted in the sides of the boxes, during the latter part of the afternoon and evening and usually dies before noon of the following day. If this is the natural life of the adult male, mating would take place in the evening or in the early morning.

**Eggs** -- The first eggs were found on July 16, 1933 and the last were found on September 13, both being from the same tree. In 1934 the scale insects on a neighboring tree commenced oviposition May 15, the season being much advanced. During the greater part of the time that the eggs are being produced the body of the female contains many developing eggs. Also, at any one time during this reproductive period, there are usually from four to six eggs under the scale cover that have been deposited but have not yet hatched. Occasionally fewer eggs are found and as many as thirteen have been counted underneath a scale cover.

The eggs are oval in shape, about .25 millimeters long and of the same bright yellow color as the adults.

On April 20, 1932, twelve eggs were removed from a female holly scale that had been growing in the greenhouse. These eggs were placed on moist filter paper in a pill box and hatched as follows: April 21--5; April 22--2; April 24--4; April 25--1.

As the eggs appear to hatch in about four to six days and there are ordinarily about this same number of eggs under a female, it might be assumed that the female does not usually deposit more than one or two eggs a day. The reproductive period being about two months in duration this insect would appear to have a rather low
reproductive potential, probably about a hundred eggs being deposited by each female. Field observations would seem to agree with this estimation as the insect not only has rather poor powers of distribution but also several years seem to be required for an infestation to assume very severe proportions.

**First Instar Larvae** -- The newly hatched larvae or nymphs, commonly known as "crawling young", remain under the scale covering of the parent for a short time, probably about two days. After having emerged from under the parent scale cover these crawling young are able to live at least twenty-four hours, but probably not more than three days, before becoming established on a host and commencing to feed. They are probably capable of traveling a few feet but if conditions are suitable they will settle down on the same leaf on which the parent scale developed. Some larvae remain underneath the parent scale and are thereby doubly protected from their enemies and spray materials by the two scale coverings. In one instance thirty-six crawling young were placed on a young holly leaf and only one specimen crawled to another leaf.

In the many examinations of holly leaves infested with the scale it was noticed that the majority of the insects on the dorsal or under side of the leaf were males and that the majority of those on the ventral or upper side were females. A count was made of the male and female scale on three twigs averaging about a foot in length, and three leaves, all fairly heavily infested with the holly scale. A total of 343 female scales were counted, of which 128 were on the
ventral side of the leaves, 5 on the dorsal side and 210 on the twigs. Of the males 13 were on the ventral side and 31 on the dorsal sides of the leaves and 28 on the twigs, a total of 72. This apparent segregation of the males and females is also shown in the photograph of infested holly leaves, (Pl. II). The samples used for both the photograph and the count were picked at random and are probably representative of the conditions found throughout any infestation.

No explanation is offered for this phenomena but it may explain why a fairly good control may be obtained with oil emulsion or kerosene emulsion (S.B. Hall (18) in spite of the fact that it is very difficult to cover the under sides of the leaves.

The first stage larvae or crawling young of the holly scale is slightly longer than the egg oval in shape with the body considerably depressed. It has six legs which are placed closer to the median line than to the lateral margins of the body. The legs, however, are long enough to extend to and slightly beyond the sides of the body. The legs are similar to other insect legs but, like the adult male, they have only one tarsal segment bearing one claw and 4 digitules or knobbed hairs. The antennae are articulated at the underside of the anterior portion of the head, rather close together and are but slightly shorter than the legs. The antennae appear to be composed of 6 segments, the distal one being longer than the others combined has several constrictions resembling segmentations, and is terminated by one or two rather long hairs. The
last abdominal segment bears a pair of lobes to which a short thread is sometimes attached, probably the waxy secretion used in the construction of the scale cover. A fringe of short hairs can be seen on the margins of the body and may be present on other parts although not distinguishable.

In this stage the holly scale does not appear to differ from other members of the sub-family Diaspidinae, at least the differences are not sufficiently outstanding to be of value for determining the species. Also at this stage the sexes can not be differentiated, unless their segregation on the upper and lower surfaces of the leaves can be considered a sexual difference.

When the crawling young scale inserts its rostrum or sucking mouth parts into the host, it is established there for the rest of its life, with the exception of the males which develop wings. Shortly after becoming established the first stage larvae commences the formation of the scale cover. This first scale cover is composed of the waxy secretion alone and is a white, downy disk that just covers the insect's body.

The completed scale covering is made up of the same waxy material; it loses its downy appearance, however, and is somewhat darker in color. The male scale covering (Pl. III fig. 1) is further strengthened by the first cast skin of the larvae and the scale covering of the adult female (Pl. III fig. 2) is reinforced by the three cast skins of the larvae.
Ecdyses or Molts -- The skin or cuticle of the holly scale insect, like that of most other insects and arthropods, is relatively inelastic, so in order that the animal can grow and increase in size it sheds its cuticle and is said to perform an ecdysis. As can be seen by the scale cover, the female holly scale undergoes three molts. The male, however, sheds its skin four times, the last three exuviae being expelled from under the scale cover.

During ecdysis, the skin of most insects ruptures along the back of the thorax and head and the insect frees its head and thorax and works the exuvia toward the caudal end of the body where it is cast off. The female scale insects of the sub-family Diaspidinae are very inactive after they commence the formation of the scale covers and would be unable to remove their exuvia in this manner. The cuticle ruptures, therefore, around or near the lateral margins, the cast skin being divided into a ventral and dorsal part. The ventral portion of the exuvia may be pressed against the leaf or other plant structure on which the insect has become established, and the dorsal portion, which is slightly thicker, is incorporated with the waxy secretion of the body to form the scale covering.

The first pellicle or larval exuvia appears to be a distinctive characteristic of the genus Aspidiotus and its allies according to MacGillivray (23). "In the genus Aspidiotus and its allies the split extends entirely around the margin of the body and the entire dorsal aspect is separated from the ventral, forming two distinct plates, a dorsal exuvia and a ventral exuvia. The dorsal plate in this case
always lacks the dried correct antennae. The dorsal exuvia forms a part of the dorsal scale and the ventral exuvia forms a part of the ventral scale, but is frequently lost." In the genera Diapis, Lepidosaphes etc. according to MacGillivray (23), the antennae remain attached to the dorsal scale and the ventral exuvia is "... rolled caudad and comes to rest upon the pygidium."

Second Instar Larvae -- The holly scale increases in size to about half a millimeter in length, requiring about three weeks for this growth, and then performs its first ecdysis. The rupture, in the specimens observed, occurred just ventral of the lateral margin and the antennae and the legs were attached to the ventral portion of the exuvia. The portion of the cuticle covering the ventral aspect of the pygidium appeared to be included with the dorsal part of the cuticle. Soon after the pellicle is incorporated into the waxy scale, an outer margin of wax is secreted to cover and protect the insect which grows beyond the limits of the small exuvia. This leaves a slightly raised central area with a lighter colored margin.

Until some time after the first ecdysis there is no apparent difference between the male and female scales. But, prior to the second molt, which occurred during the early part of December in 1933, the males could be readily distinguished by the distinct elongation of the scale covering and the walls of wax built around the lateral and cephalic margins of the male insect. There was also a change in the body of the males; they became slightly elongated and a pair of distinct, purplish eyespots or ocellana appeared on the
anterior part of the head.

The females, in this second instar, are about 1.5 millimeters in length, oval in shape with the widest portion slightly before the middle of the body. The males are of about the same size as the females and retain their mouthparts and pygidal structures. The only apparent difference between the male and female insects in this stage is the slightly more elongated shape and the development of the ocellana of the male.

**Third Instar Female** -- The manner of removing the second exuviae was not observed but MacGillivray (23) in discussing the development of the scale insects of the sub-family Diaphidinae, states that: "When the insects of this stage molt, there is no variation in the way in which the cuticle ruptures, but in all species there is a transverse rupture on the ventral aspect cephalad of the rostrum which connects on each side with the lateral margin, the further rupture of the cuticle extends caudad along each side to the pygidium. The ventral portion of the exuvia is rolled back upon the caudal portion of the ventral aspect of the body."

The whole of this second exuvia of the female is incorporated into the dorsal scale covering which is soon enlarged by a further addition of wax around the margin to cover the growing insect. This exuvia shows through the wax a little lighter shade of brown than does the first cast skin.

The female remains in this instar, growing but slightly larger, until after fertilization takes place or the eggs begin to develop.
The increase in size, due to the developing embryos, apparently necessitates the third and last ecdysis of the female. Although there is relatively little growth of the insect after this last molt, the scale covering is considerably increased in size to make room for the eggs and young larvae.

**Male Prepupae and Pupae** -- The second molt of the male takes place at about the same time as that of the female but the exuvia, instead of being incorporated into the scale cover, is extruded under the posterior part of the cover. Following this molt the male is in a stage which has been called the prepupae, (Pl. IV fig. 1). The body is more elongated and a distinct head, thorax and abdomen are distinguishable. The eyes or ocellana are more definite than in the preceding stage, and the antennae, legs and wings are represented by stout palpi-like appendages that are held closely to the body. The structures of the pydgium as present in the preceding stage have disappeared with the exception of a pair of small lobes. The mouth parts are lost and the males are no longer able to feed.

The prepupal stage was found in the latter part of January and early February of 1934, the true pupae being present in the latter part of February and in March. The emergence of the adult males commences in the latter part of March, 1934.

The true pupae resembles the prepupae in general shape but is somewhat slenderer and the legs and antennae have lost the palpi-like appearance. The thorax is slightly darker than the abdomen and the pair of small lobes on the abdomen of the prepupae have dis-
appeared. A spine-like projection, in which the stylus will develop, is present on the caudal end of the abdomen.

The exuviae from both the pre-pupae and the pupal stages, as well as the second larval exuvia of the male, are forced out under the posterior part of the scale cover. The adult, with its wings fully developed (Pl. III fig. 1) apparently rests under the scale cover for a few hours and then emerges. The insect escapes from under the cover by backing out; the wings fold back over the head and are pulled out last.
### TABLE 4

**SEASONAL LIFE HISTORY OF THE HOLLY SCALE THROUGH 1933 AND PART OF 1934**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1933</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>third instar</td>
<td>adult</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>eggs</td>
<td>first instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>second instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1934</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>third instar</td>
<td>adult</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>eggs</td>
<td>first instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>second instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1933</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>pupae</td>
<td>adult</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>eggs</td>
<td>first instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>second instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1934</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>prepupae</td>
<td>pupae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>adult</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>eggs</td>
<td>first instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>second instar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ecology and Natural Control of the Holly Scale

The most important factors in the natural control of the holly scale appear to be the two chalcid parasites that were found to attack this pest. Other natural ecological factors may affect the holly scale, but were not observed to result in any appreciable control.

The wide distribution of the holly scale compared with the relatively limited area in which English holly is grown would seem to indicate that the insect is more resistant to extreme or adverse climatic conditions than is this host plant.

Low Temperature -- The Pacific Northwest experienced unusually cold weather in the winter of 1932-33. The temperature was considerably below normal throughout most of the holly shipping season. Some of the holly that was cut and shipped during this period was found, on reaching its destination, to have suffered severe injury. In many localities the trees were slightly injured, blackened areas appearing in the leaves. These dead and discolored portions of the leaves dried up and later fell out, leaving irregular holes in the leaves somewhat resembling the type of injury that might be caused by a chewing insect. Many specimens of infested holly were examined during and after this cold spell but in no case were scale insects found that gave any indication of having been injured by the low temperatures.
High Temperatures -- The English holly is not a tropical plant and does not appear to thrive well in tropical or even semi-tropical countries. The scale insect, however, lives well in greenhouses, until reduced by parasites or applied control measures, and is reported from tropical and sub-tropical countries as is shown in Tables 1 and 2. From these observations it might be assumed that the insect is more resistant to high temperatures than is the host plant, English holly.

Sunlight -- Intense, prolonged sunlight might be a factor in the destruction of the holly scale. But, again, English holly appears to grow to its best advantage in shade and such exposure would probably be more damaging to the host than to the insects. Also the scales are usually found to be more abundant on the lower branches of the bush or tree and would be protected by the dense foliage. Severe pruning, which would also facilitate better coverage with spray material, might be a direct factor in controlling the scale by permitting better penetration of the sunlight. The first stage larvae would be most likely to be affected by this treatment as they lack the protection of the scale covering.

Rain -- Because of the waxy, water proof scale covers, the adult holly scales would appear to suffer little if any injury from precipitations. The unprotected first stage larvae, however, might be washed from the host plant or drowned by heavy rains. As there is usually very little rain during July and August and the early part of September, rain is probably a very minor factor in the con-
trol of the holly scale.

**Wind** -- Investigations by J.H. Quayle (31) show that wind is the greatest factor in the local distribution of the black scale, *Saissetia oleae* (Bernard) and the red scale, *Chrysomphalus aurantii* (Maskell).

A total of 7,262 young black scales were collected by Quayle on twenty-one tangle foot sheets in three days, during June, 1915. These sheets were placed from 10 to 450 feet from the infested tree and were from 2 to 6 feet above the ground level. The size of these tangle foot sheets is not given but they would undoubtedly represent only a small portion of the area over which the scales are blown. Also the experiment was conducted for only three days, whereas the reproductive period of the black scale is said to extend from April to September. It would appear, therefore, that a tremendous number of these insects are carried from the host plant by the wind.

In an earlier publication by the same author (30) it is shown that these scale insects have very limited powers of locomotion. As they are apparently able to walk only a few feet under ideal conditions they are almost entirely dependent on other agencies for distribution from one tree to another.

In view of this information it would seem that wind might have a two fold effect on scale insects. First as an agent in their distribution and secondly as an adverse factor in that many of the young scales would be blown from the tree and unable to locate a suitable host plant. The ultimate effect of the wind on such species of
scale insects would probably depend on the reproductive powers of the species, duration and velocity of wind during the reproductive period and the degree of protection from the wind offered by the habitat.

The black scale, reported to lay about two thousand eggs, is able to increase in numbers in spite of this apparent loss. The holly scale, however, would be greatly affected by such a loss as the average female appears to lay only about a hundred eggs. On the other hand, the black scale on citrus trees is quite high above the ground and is exposed to the wind while the holly scale is usually quite close to the ground and is protected from the wind by the dense, stiff foliage.

The holly scale appears to have quite feeble powers of distribution, probably because of this relation to the wind. For example, two of the trees on the property in Portland were very heavily infested while another tree not over fifteen feet away had a very light infestation. Similar examples were found in connection with other infestations.

These observations would seem to indicate that the meteorological conditions, such as the temperature variations, sunlight, rain and wind have very little effect on the adult scale and do not appreciably control the immature forms.

Viability of Insects on Cut Holly -- Examinations of the scale insects on the leaves, twigs and berries of cut holly samples indicate that the immature scale insects and adult females die when the
plant has lost the greater part of its water content. During the winter, at room temperature, this usually occurred in less than two weeks. The males, however, do not feed after reaching the prepupal stage and are not appreciably affected by the drying of the host plant. Also, the mature females are quite resistant to the drying of the host plant, and have been observed to continue to deposit eggs three weeks after the leaves had been removed from the plant. The length of time that the insects would remain alive on cut holly would vary with the temperature and humidity of the environment as well as with the sex and stage of development of the insects. Also, some varieties of holly appear to maintain their fresh green appearance longer than others and the scale insects on these plants would probably remain alive longer than on other varieties.

Some insects and birds are considered to be somewhat instrumental in the distribution of the holly scale. Many of the common birds and such insects as bees, wasps, syrphid flies and others are frequently found on holly and it would seem quite possible that the first stage larvae could attach themselves to these larger, more motile forms and be carried to other host plants.

Some birds may also affect the holly scale by feeding on these insect pests. According to most authorities, birds are not an appreciable factor in the natural control of scale insects. Newstead (27), however, has made stomach analyses of at least three species of birds, the blue titmouse, *Parus caeruleus* Linn; the long tailed titmouse, *Acredula caudata* Linn. and the jackdaw, *Corvus monedula*
Linn; and found that a large part of their diet was made up of scale insects. On the strength of the stomach analyses and field observations Newstead states, (27) "Here in England I have proved beyond doubt that certain insectivorous birds feed very extensively upon coccids, . . ."

Bare spots are occasionally found on holly leaves that otherwise were heavily incrusted with the scale insects. These spots were previously covered with the scales and show light yellow in color. These scales may have been eaten by birds or removed by mechanical means. In either event birds are a very small factor in the control of the holly scale, if they attack it at all.

Mr. Scullen reports that considerable fungus was found in some specimens of the holly scale prepared for class use.

Parasitic Insects

Two species of chalcids, *Aphytis (Aphelinus) mytilaipidis* (Le Baron)* and *Aspidiotiphagus citrinus* (Crawford)* were found to be quite abundant on holly scales in Portland and are reported to be rather common parasites in many parts of the world attacking many scale insects.

It would probably not be economical to utilize or depend upon either or both of these parasites for control of the holly scale in

* Determined by P.H. Timberlake, Riverside Experiment station, and A.B. Gahan, Division of Identification and Classification of Insects, United States Bureau of Entomology.
the field. Infested plants growing in a green house, however, appear to require no further treatment if at least one species of these aggressive chalcid parasites is present.

The failure to maintain an infestation of the holly scale in the green house is attributed to the work of *A. mytilaspidis*. There was no record of the room having been fumigated and also a species of white fly and a soft scale were present in the same compartment.

Dietz and Morrison (11) state that an infestation *A. britannicus* was found in a green house in Indiana but that it was difficult to obtain specimens for study because of the abundance of parasites.

This insect pest was reported from holly in Boston, Massachusetts in 1902, (20). But apparently it has not become a serious pest in that state. According to a letter from A.I. Bourne, Professor of Research Entomology, Massachusetts State College, this insect has not been brought to the attention of the entomologists in that state in recent years, nor is there any record of recent collections of the holly scale in Massachusetts. Possibly the parasites eradicated the pests in the green houses in Massachusetts and climatic conditions or lack of suitable hosts prevented it from becoming a pest elsewhere.

*Aphytis mytilaspidis* -- The first adult parasite found in December 1932, was *A. mytilaspidis* (Pl. VI fig. 1), the larvae having been noticed earlier in the winter on holly sent from Portland by Mr. Wieman.

The distribution and hosts are given by E.O. Essig (15) "... Oc-
curs throughout Southern Europe, the United States, and is common in California. Parasitic on Diaspis carueli Targ., Aulacaspis rosae (Bouche), Chionaspis pinifoliae (Fitch), Lepidosaphes ulmi (Linn.), Aspidiotus hederae (Vall.), and A. perniciosus, Comst.

Further research would undoubtedly show a wider distribution and increase the list of suitable hosts.

The adult of this parasite (Pl. VI fig. 1) is about the same color and size as the male scale. It has two pairs of wings, however, which are of about the same length but the mesa-wings are more than twice as wide as the meta-wings. The hairs fringing the wings are not more than about half as long as the widest part of the meta-wings.

The larvae of this chalcid lives underneath the scale cover, feeds externally on the scale insect, and leaves very little of the host unconsumed. Usually there is but one parasite to a host but occasionally there are two, and three larvae were found feeding on one holly scale. These three larvae pupated, the pupae being much smaller than average, and were placed on moist filter paper in a pill box. Mold grew over these specimens, apparently causing their death before the emergence of the adults.

The mature larvae are of the same bright yellow color as the hosts, about a millimeter in length and almost spherical in shape, the anterior end being slightly taper to the mouth. A dark spot is noticeable inside the body. On dissection, this appears to consist of the feces which are retained within the body until just before
pupation. The larvae have no appendages and are capable only of movements of the body. When disturbed, the head and anterior part of the body is moved back and forth quite vigorously.

The pupae are formed underneath the scale cover of the host and are surrounded with several dark brown or black fecal pellets which are excreted just prior to pupation. The adult emerges from underneath the scale cover without piercing this covering.

This insect appeared to winter as immature and mature larvae, the pupae being formed in the early spring. Although the eggs were not observed, these insects appear to be present in all stages throughout the summer and fall.

The parasite is probably unable to complete his development on the holly scale until this host has reached the second instar. If this is so, the parasites would continue to reproduce on the old females until the young scale insects developed to a suitable size. This observation is offered as an explanation for the apparent difference in the effectiveness of this parasite in controlling its host on plants growing under glass and out of doors. Or, rather, it might be considered a natural provision to prevent the parasite from completely destroying its hosts and being forced to find other hosts or become extinct.

Aspidiotiphagus citrinus -- The other chalcid A. citrinus* was

*A rather complete treatise of this parasite was published by Quayle (32) in connection with its host, the red scale, C. aurantii, in California.
first found in November of 1933. Although scale covers, pierced with the emergence holes of this or a similar parasite, (Pl. III fig. 2) had been noticed occasionally during the previous winter.

Regarding the distribution and hosts of this insect Essig (15) states, "A very common and beneficial species occurring in Southern Europe, Brazil, California, and the tropical Pacific Islands. Parasitic on Aspidiotus ancylius (Ptn.), A. hederae (Vall.), A. perniciosus Comst., A. pini Comst., Aulacaspis rosae (Bouche), Lepidosaphes beckii (Newm.), L. ulmi (Linn.), Chrysomphalus aurantii (Mask), C. citrinus (Coq.), C. aonidum (Linn.), and C. dictyospermi (Mor.) in California. It is very common on Pinnaspis aspidistrae (Sign.) on coconut palms in the Pacific South Sea Islands."

From this rather long host list it might be assumed that this parasite is able to attack most if not all of the armored scales.

The adult of this chalcid (Pl. VI fig. 2) is about half as long as the other parasite, being about .75 millimeters in length. It is considerably darker in color and has a dark band across the abdomen. The forewings are quite narrow, compared with those of A. mytilaspis, and the hind wings are very narrow. A darker, infuscated area extends across the middle of each wing. The marginal hairs on the wings are very long, the longest being almost twice as long as the width of the fore wings.

The larvae of A. citrinus (Pl. V fig. 2) are usually found in a somewhat curved position inside the body of the host. The two parasited holly scales in this illustration are both males in the
latter part of the second instar. All parasitised specimens observed, both male and female, were in the second instar scale insects. Usually but one parasite was found in a host but on one occasion two parasites were found in one host. It is not known whether two or more chalcids are able to reach maturity in a single individual.

It is very difficult to see the larvae in an unstained mount as they are either colorless or of about the same color as the host. The larvae are readily distinguished, however, in parasitised hosts stained with either acid fuchsins or analine blue stains.

The pupae (Pl. V fig. 1) are formed in the body of the host and may be either parallel or perpendicular to the long axis of the body of the scale insect. With this parasite also, the feces appear to be passed just prior to pupation and are seen as dark bodies almost surrounding the pupae. The adult emerges through a more or less circular hole which it cuts in the dorsal side of the host and the scale cover. (Pl. III fig. 2)

A. citrinus appears to winter in the larval stage also. Specimens reared through on infested holly scales in the green house and on holly cut and placed at room temperature, commenced emergence several days before the first adults of A. mytilaspidis appeared.


10. Dallimore, W. Holly, Yew and Box


<table>
<thead>
<tr>
<th>No.</th>
<th>Author</th>
<th>Title</th>
<th>Publisher/Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.</td>
<td>Hall, S.B.</td>
<td><em>Controlling Holly Scale, A Progress Report on 1931 Demonstration Trials</em></td>
<td></td>
</tr>
<tr>
<td>23.</td>
<td>MacGillivray, A.D.</td>
<td><em>The Coccidae</em>. Scarab Co., 1921</td>
<td></td>
</tr>
</tbody>
</table>
37. Wunn, H. Sudliche Schildlaue im Rheintal (Southern Scale Insects in the Rhine Valley) Zeitche angew Ent. X No. 2, Berlin, 1924
Plate I

Pygicium of Holly Scale

Aspidiotus britannicus

greatly enlarged
The holly scale, *Aspidiotus britannicus*, on English holly leaves. Upper left—female scale covers of the previous year; upper right—upper side of leaf, showing principally female scale covers; lower center—under side of leaf, showing principally empty male scale covers.
Fig. 1
Adult male holly scale underneath scale cover, ventral view. (x50)

Fig. 2
Scale cover of adult female holly scale. (x50)
Fig. 1
Prepupa of male holly scale. (x50)

Fig. 2
Adult of male holly scale. (x50)
Fig. 1

*Aspidiotiphagus citrinus* in holly scale insect. (x50)

Fig. 2

*Aspidiotiphagus citrinus* larvae in holly scale insect. (x50)
Plate VI

Fig. 1

Adult *Aphytis mytilaspides*.

Fig. 2

Adult *Aspidiotiphagus citrinus*.